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SEPTEMBER 1985

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FEATURES

DEPARTMENTS

KEVIN CONKLIN

Keeping up with technology: the new executive style

As technology's pace accelerates, an important shift is taking place in America's boardrooms and corner offices. The classic executive read financial reports, kept up with the latest management fads, belonged to the right clubs, and made deals. His main criteria for decision-making were avoiding risk and maximizing short-term profits. Oh yes, there were factories and workers and salesfolks and techies out there plugging along every day. But for the executive to know about all that was essentially irrelevent to running the business. Knowing the right congressmen and tax-shelter lawyers proved much more critical for creating a favorable business climate.

Some dramatic changes in the marketplace are beginning to disrupt this clubby management lifestyle. Factories, companies—even whole industries—that seemed to be moving steadily along have suddenly had the bottom drop out. And the culprit hasn't always been some foreign government-backed industry employing 10¢-an-hour labor. The new challenge may be coming from newcomers using innovative technology to create a new way of doing things. On closer inspection, even invaders from overseas are often found to be succeeding more because of advanced products and manufacturing processes than because of cheap labor.

Ironically, it's the cautious and conservative executive—the one who carefully avoids risk and boasts about healthy balance sheets—that now often ends up falling off the cliff or being attacked by corporate raiders.

That's why recognition of the need to be venturesome is rising like the tide throughout the business community. The entrepreneurial spirit of the technology hotshots is beginning to seep from industry and university labs into the boardrooms of America's largest corporations. Some, like General Motors, are buying up innovative technology firms, hoping to tap their special expertise—not only to develop new market opportunities but also to help transform their own sluggish organizations. Others, like IBM and Control Data, are setting up "intrapreneurial" subsidiaries, hoping to nurture bright new ideas that can become their businesses of tomorrow.

Standing pat is no longer the safe route. The corporation that is going to succeed is busily finding ways to improve its manufacturing methods, communications, distribution, and buying and marketing techniques, as well as its products and services. The old management routine—wandering the golf course, cutting deals, romancing Wall Street—won't do anymore. The new-style executive is getting out into the factories, moving technical people into key positions (many are technically trained themselves), and learning about new technologies that may offer opportunities for his (or her) organization.

It's about time.

Robert Haavind

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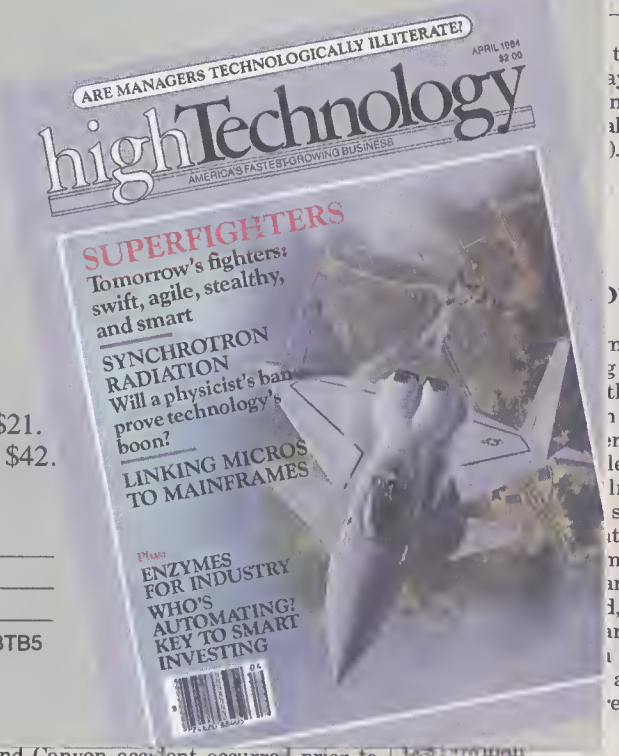

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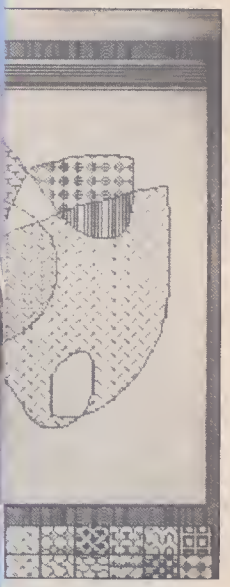

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of those who buy undervalued assets, rather than investing in technological innovation, is weak in several places (Opinion, July, p. 4). One of these is worth mentioning.

Over time, inventors have come to see their ideas as vehicles for getting rich. Sometimes they do their research in big company labs, sandbagging their employers until they can jump ship and find the financing to go off on their own. In other cases, the inventor has an unrealistic opinion of the value of his technology and the ease with which an idea can be made into a profitable company.

At the same time, there is plenty of venture capital around. Inventors with stars in

Grand Canyon accident occurred prior to the time airliners were required to fly on instrument flight plans. Such examples are routinely used to justify requiring planes to carry extra traffic control equipment.

There is a pressing need for high technology in civil aeronautics. But R&D needs prioritizing for maximum benefit. An ancillary collision avoidance system should have a very low priority. Some examples of more critical needs:

- An updated traffic control system (today's uses 1960s technology).
- Navigation systems, perhaps using satellites, that are better than today's VHF system from the 1940s.

Pacific Projects
Washington, D.C.

Editor's note: The contact for Peat, Marwick's National Technology Practice ("Accounting firms bid for high tech business," June, p. 68) is S. Thomas Moser, 80 S. 8th St., Minneapolis, MN 55402, (612) 341–2222.

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It's about time.

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KEVIN CONKLIN

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LETTERS

Another technology lost to Japan?

I am a founder of Panelvision, a pioneer and recognized leader in the field of high-performance flat panel displays. My company developed and put on the market the world's first "active matrix" displays—essentially gigantic integrated circuits capable of presenting a television image or computer graphics.

Flat panels have become very fashionable. Almost every computer company has marketed or intends to market compact laptop computers using such screens. However, the present generation of (Japanese) flat screens is inadequate and has received a justified panning from the press. Active matrix technology is capable of generating flat screens with a performance identical to that of the cathode-ray tube and will eventually surpass the tube. This is generally recognized by display experts, and in consequence Panelvision today is hotly pursued by the Japanese electronics industry.

Despite its credentials and scope, Panelvision is now in liquidation, having been unable to raise the $5 million it requires to install enough production equipment to reach break-even. Apart from the venture capital community, we have approached at least 70 potential corporate investors and have been turned down by all of them. Not one of them was willing to accept the risk.

The patient and difficult creation of new industries, new markets, and new jobs looks unappealing to our financial community. They are willing to leave it to the Japanese, but then what happens to the rest of us?

It is still possible for my company to get a last-minute reprieve. Should we fail, Pittsburgh will have lost 40 new jobs, the U.S. will have lost a major new industry originally created here, and I will become a consultant teaching the Japanese how to fabricate high-performance flat screens.

T. P. Brody, Vice-Chairman
Panelvision Corp.
Pittsburgh, Pa.

Starry-eyed inventors turn off investors

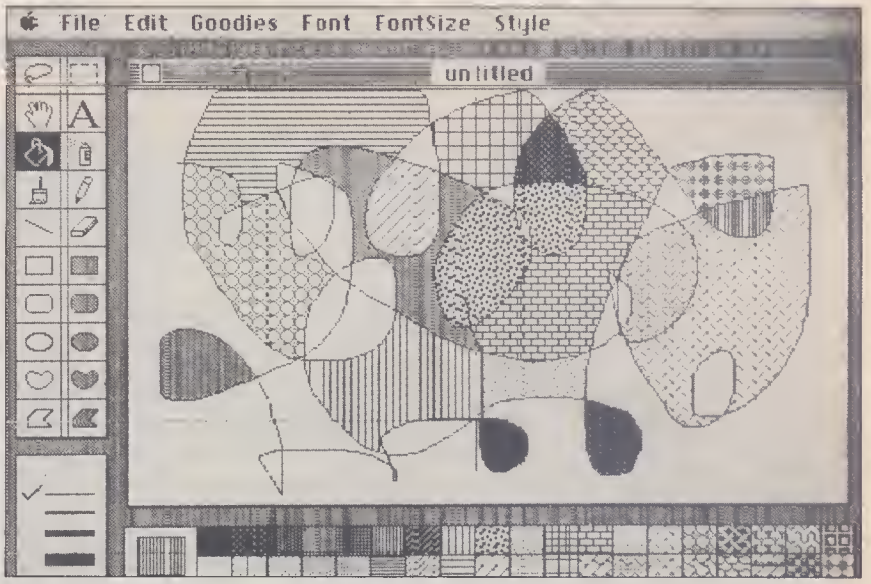
Your argument as to the wrongheadedness of those who buy undervalued assets, rather than investing in technological innovation, is weak in several places (Opinion, July, p. 4). One of these is worth mentioning.

Over time, inventors have come to see their ideas as vehicles for getting rich. Sometimes they do their research in big company labs, sandbagging their employers until they can jump ship and find the financing to go off on their own. In other cases, the inventor has an unrealistic opinion of the value of his technology and the ease with which an idea can be made into a profitable company.

At the same time, there is plenty of venture capital around. Inventors with stars in their eyes present deals to institutional investors under pressure to invest funds that are not their own. The result has been "deal inflation," a near sure route to losses.

This has caused many investors, including the firms with which I am associated, to pull out of what has become a loser's game and to invest in undervalued assets.

Joseph Sullivan, Vice-President
Renaissance Group
Dallas, Tex.



Panelvision claims that its active matrix screen, here displaying Macintosh graphics, will eventually outshine the cathode-ray tube.

R&D priorities for air traffic control

The facts you presented in "Preventing midair collisions" (July, p. 48) are misleading. For example, the San Diego disaster was caused when an FAA controller vectored two aircraft into each other. Both planes were under "positive control" (i.e., on instrument flight plans), both were professionally flown, and both were exactly where they were directed to be.

The horrifying concept of two jumbo jets colliding could occur only if FAA controllers (or the pilots) violated procedures. The 1956 Grand Canyon accident occurred prior to the time airliners were required to fly on instrument flight plans. Such examples are routinely used to justify requiring planes to carry extra traffic control equipment.

There is a pressing need for high technology in civil aeronautics. But R&D needs prioritizing for maximum benefit. An ancillary collision avoidance system should have a very low priority. Some examples of more critical needs:

- An updated traffic control system (today's uses 1960s technology).
- Navigation systems, perhaps using satellites, that are better than today's VHF system from the 1940s.
- Better control on the ground to prevent runway collisions (maybe traffic lights).
- Better flight planning services (weather briefings on personal computer nets are better than the FAA's).

John Trudel
Beaverton, Ore.

More uses for platinum

"Go for the platinum" (July, p. 54) did a good job of describing the major industrial and medical uses for the metal. But it omitted an important high tech application.

Platinum and other precious metals are widely used in the electronics industry in the form of thick film paste. Thick film technology involves screen-printing films about 1 mil thick onto an insulating substrate and fusing them through firing.

Thick film pastes are a mixture of heat-curing resin and gold, silver, or platinum-family metals. Research is proceeding on replacing these with less expensive base metals, but for many applications precious metals are still required.

Les Bowman
Pacific Projects
Washington, D.C.

Editor's note: The contact for Peat, Marwick's National Technology Practice ("Accounting firms bid for high tech business," June, p. 68) is S. Thomas Moser, 80 S. 8th St., Minneapolis, MN 55402, (612) 341–2222.

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UPDATE

Venture capital seeks out midwestern entrepreneurs

A lot of venture capital money comes from the Midwest, but it seems to gravitate out of the region, say many observers, especially into start-up companies on the West Coast. Now, Chicago-area venture capitalists have a new forum for learning about promising Midwestern entrepreneurs: the Chicago Venture Capital Club. The club plans to meet four times a year to hear formal presentations from several entrepreneurs, chosen on the basis of business plans submitted in advance. At its first meeting, attended by 70 venture capitalists from 38 Midwest firms, five start-ups participated—all high tech ventures. However, the club hopes to showcase companies in a variety of fields and at different stages of development, says Jack Staley, one of the group's founders and a partner in the accounting and consulting firm of Arthur Young.

The club's next meeting will be held November 4. Midwestern entrepreneurs who would like to make a presentation should send their company's business plan to the Chicago Venture Capital Club, attn: Colette Gibbons, c/o Arthur Young, One IBM Plaza, Chicago, IL 60611.

If you can't stand the heat, get a cooler stove

"Slaving over a hot stove" may soon join the washboard in housework history. An experimental gas burner throws off 60% less waste heat than conventional units, promising a more comfortable kitchen, lower air conditioning bills, and cleaner indoor air, according to the Gas Research Institute (GRI) in Chicago, which is sponsoring development.

The burner transmits heat primarily by radiation rather than convection. Gone are the blue flames licking the pot. Instead, a premixed gas–air stream is forced upward through hundreds of holes in a honeycomblike ceramic tile. The gas ignites at the tile surface, and the glowing ceramic throws heat up through a spill-protecting glass plate to the cooking vessel. To increase efficiency, the hot exhaust gases are jetted through holes in the glass plate. The burner consumes only 7000 Btu of gas per hour, versus 9000 Btu for a conventional unit of the same cooking capacity, according to GRI project manager John Lockwood. Another advantage: Because it's relatively cool, the burner emits only a fifth as much unhealthful oxides of nitrogen.

Ceramic tile radiates heat in a cleaner, more efficient gas burner.

The burner is being developed jointly by Thermo Electron (Waltham, Mass.) and Caloric (Topton, Pa.) and should be available by year's end. But the developers have to work out a few kinks before they're "cooking with gas." The glass plates tend to crack after a few hours of use, and the flame cannot be sustained below a third of its highest setting. Polishing the glass holes should eliminate cracking, says Lockwood, but improvements in the "turndown ratio" may come at the expense of efficiency.

Automated chip design gets affordable

The day of the workstation on every electronic engineer's desk has come a step closer. Viewlogic Systems (Marlboro, Mass.) has introduced software for interactive circuit design, simulation, and documentation that runs on a conventional IBM PC/XT or AT. For between $3500 and $8500 plus the price of a suitable PC, the Workview computer-aided engineering package has capabilities previously available only on a larger dedicated workstation (for $40,000 and up) or a PC with an added 32-bit coprocessor (about $20,000).

Developed by a group of former Digital Equipment Corp. engineers, Workview is available in versions for designing either analog or digital integrated circuits. A sophisticated windowing system allows the designer to view circuit elements and their corresponding waveforms simultaneously during simulation.

Described by Viewlogic president Alan Hanover as "the first personal CAE workstation," Workview allows graphics and text to be combined so that schematic diagrams and simulated waveforms can be conveniently inserted into the designer's report, and its communications capabilities allow the transmission of completed designs to other engineers or to a larger computer for automated physical layout.

An industrial trade policy for the U.S.

by Michael E. Brose
President, Technology Consulting Group

In countries such as France, Germany, and Japan, government and industry have formed partnerships in order to attain national objectives in employment and trade. When American companies try to sell there, for example, they face formidable economic barriers. And when they compete with companies from these nations in other global markets, they are competing with the governments as well.

Meanwhile, imports of manufactured products continue to flood the U.S. market. The U.S. trade deficit, which in 1973 was only about $5 billion, had grown to $60–70 billion by 1983 and is projected to be $200 billion by 1990. But those are just overall statistics. When you look at the trade balance with specific countries—Japan, for example—you begin to see the real problem: Six of the top seven United States exports to Japan are agricultural products and minerals, but virtually all the Japanese exports to the U.S. are knowledge-intensive, high-value-added products—the kind that create manufacturing jobs for skilled workers.

Inexplicably, the United States remains the only industrialized country that thinks it can exist with a "free trade" policy. Others are looking out for their own interests, while America is giving away the store.

I believe we've got to do something, and do it soon. We will need to replace some of our past practices with new and innovative ones—perhaps even adapt some of the approaches of other countries—while retaining what is best about the American system. And it should all be done in the context of an explicit industrial trade strategy for the U.S., jointly developed by a partnership between industry, labor, and government.

When I say U.S. industrial trade strategy, I mean a set of policies and actions that will allow American companies to compete on a reasonably fair and equitable basis in international trade. I'm not proposing a government planning agency that decides what industries to bet on for the future—the so-called "sunrise and sunset industries" concept. Instead, let's make it possible for all American industries to meet foreign competition without having their hands tied behind their backs.

How? Here are some recommendations:

Promote the need for an industrial trade strategy. American businesspeople must initiate a massive and vigorous program to enlighten our government officials about the critical links between a strong industrial base and the country's national goals. And because we're all in this together, we need to have a coalition of management and labor involved in presenting the case for an industrial trade strategy to Washington. Mobilizing our industry trade associations and unions for this task should be the first step toward creating a national awareness of the urgent need for action; spurring Congress to conduct hearings on industrial trade strategy should be the second.

We must negotiate forcefully for reciprocal trade based on similar types of goods.

Adopt reciprocal trade policies. To maintain a viable industrial base, we've got to stop exporting primarily agricultural products while importing mostly industrial products. We must direct our trade officials to negotiate forcefully for reciprocal trade based on similar types of goods. If Japan sells $1 billion worth of semiconductors to the U.S. market, for example, then American firms should be able to sell $1 billion worth of semiconductors in Japan. Alternatively, we might negotiate an offsetting amount for a related market, such as telecommunications or computers, but not wheat or soybeans. Until a reciprocal trade policy can be fully implemented, the U.S. should adopt a system of quotas and tariffs, as well as subsidies, to enable firms to compete with foreign government-subsidized imports in such key areas as steel, automobiles, semiconductors, computers, and telecommunications.

Create new incentives for industrial investment. Our high interest rates, the budget deficit, and the strength of the U.S. dollar against foreign currencies are all critical issues that must be addressed in order to create a more favorable investment climate. But that will not be enough. The trade problem facing industrial America is more fundamental; its dimensions were apparent in the mid-'70s, long before these issues arose.

Government policies must be revised to make industrial investment in new process technology and plant modernization more attractive. The government should negotiate arrangements with key industries whereby it will impose quotas or tariffs on imports in exchange for the industry's investment in modernization of facilities. The U.S. also needs to consider new tax

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An industrial trade policy for the U.S.

by Michael E. Brose
President, Technology Consulting Group

In countries such as France, Germany, and Japan, government and industry have formed partnerships in order to attain national objectives in employment and trade. When American companies try to sell there, for example, they face formidable economic barriers. And when they compete with companies from these nations in other global markets, they are competing with the governments as well.

Meanwhile, imports of manufactured products continue to flood the U.S. ma
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strategy, I mean a set of policies and actions that will allow American companies to compete on a reasonably fair and equitable basis in international trade. I'm not proposing a government planning agency that decides what industries to bet on for the future—the so-called "sunrise and sunset industries" concept. Instead, let's make it possible for all American industries to meet foreign competition without having their hands tied behind their backs.

trial trade strategy should be the second.

Adopt reciprocal trade policies. To maintain a viable industrial base, we've got to stop exporting primarily agricultural products while importing mostly industrial products. We must direct our trade officials to negotiate forcefully for reciprocal trade based on similar types of goods. If Japan sells $1 billion worth of semiconductors to the U.S. market, for example, then American firms should be able to sell $1

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policies and accelerated depreciation schedules that reflect the rapid rate of technological change and the necessity of reinvesting continuously in productive assets. We must also provide for the retraining of workers displaced by factory automation. And instead of using our antitrust laws to prevent all types of cooperation between firms in an industry, we should seek ways of providing research funds for joint industry efforts in new and commercially promising areas of technology.

Seek new management approaches. We must assess whether or not the business community's practices of the past 20 or 30 years are still applicable to the global marketplace of today. In labor–management relations, for instance, we've already seen how a higher degree of worker participation has contributed to tremendous improvements in quality and productivity. We need to rethink our policy of investing overseas rather than in the U.S., particularly in light of the positive impact that factory automation can have on production costs. Managers must reassess their responsibilities toward their employees and the community: While making a profit is certainly an aim of business, there are other objectives, such as providing meaningful work opportunities. We need to evaluate whether many of the measures we use for management performance are still valid; emphasis on earnings per share and return on investment, for example, has favored management for short-term results instead of long-term growth. Finally, we must determine whether it is really better for companies to grow by acquisition than to grow by investing in new technology of their own.

Other countries are looking out for their own interests, while the United States is giving away the store.

"If we stand idly by," said Theodore Roosevelt, "then the bolder and stronger peoples will pass us by and win for themselves the domination of the world." But I don't believe we will. I fully expect that management, labor, and government will unite, find their voice, and make themselves heard in Washington to achieve our common goals; that we will again build new factories in America instead of tearing them down; that all our people will be productively at work; and that American ingenuity will bloom once again and be second to none. □

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BUSINESS STRATEGIES

Ashton-Tate:
SOFTWARE IMPRESARIO ON AN EXPANSION SPREE

Two of the country's top microcomputer software companies, Ashton-Tate (Culver City, Cal.) and Lotus Development Corp. (Cambridge, Mass.), have been carrying on like the Hatfields and the McCoys ever since they announced competing packages—Framework from Ashton-Tate and Symphony from Lotus—that combine popular office functions such as database management, spreadsheet analysis, and word processing. The feud started with newspaper, magazine, and TV ads, but it soon spilled over into a contest to acquire new programs and even entire software development staffs. Both companies realize that to be successful in a maturing market, they must continue to innovate with a vengeance. For Ashton-Tate, this means significantly expanding its role as a savvy marketer of programs created by others and becoming a full-scale software developer itself.

Ashton-Tate sharply escalated its acquisition efforts after it lost a battle with Lotus in early April to buy Software Arts, creator of VisiCalc, the first microcomputer spreadsheet program. Not only did the $4 million purchase price give Lotus rights to VisiCalc and several newer programs, but it also included an agreement that VisiCalc's two authors will join the Lotus development team. Ashton-Tate countered by announcing its intention to buy Forefront Corp.—the company that developed Framework—a purchase that will increase its own programming staff by almost 50%.

The new emphasis on acquisition is only one aspect of an overall attempt to get "more aggressive to sustain growth and combat adverse market conditions," says Ronald Posner, executive vice-president in charge of marketing, sales, and international operations. Ashton-Tate has invested substantially to widen its markets—first in Europe, where its strong presence generated most of the 22% that international sales contributed to revenues for the year ending last January 31, and then in Australia and Far Eastern countries such as Japan, where it recently formed divisions. In April, Ashton-Tate announced an agreement giving it exclusive rights to market the entire line of a software company it so far refuses to name. And in May, the company signed an agreement with Software AG, a leading mainframe software vendor, to jointly develop and market a microcomputer-to-mainframe link for transferring data between their respective packages. (Ashton-Tate signed a similar agreement last year with another top vendor of mainframe software, Informatics General.) By early summer, Ashton-Tate was reviewing "three or four proposals a week for acquiring companies, authors, or products," says Posner.

Ashton-Tate is aggressively acquiring companies, authors, and products, says executive vice-president Ronald Posner.

BRETT FROOMER

Ashton-Tate's attempts to broaden its product line hold the greatest potential for growth, believes Michael Orsak, a software industry analyst for market research firm Input (Mountain View, Cal.). "There are only a handful of companies that have the name, money, and distribution channels to branch out," he says, and Ashton-Tate is one of the few microcomputer software companies that have already penetrated more than one market successfully. Its popular dBase packages have made the company the undisputed leader in the market for microcomputer database management programs, estimated by Input at $240 million in 1985 for the U.S. alone. And Framework has put Ashton-Tate among the top four vendors of integrated business packages for micros, according to Input, which estimates the U.S. market for such programs at $440 million this year. Despite first-quarter earnings of $24 million (up from $11 million in the first quarter of 1984), the company needs to branch out still further, Orsak contends, to catch up to Lotus's revenues of $157 million for fiscal 1984. Over 75% of Ashton-Tate's $82.3 million in revenues for the year ending last January 31 came from sales of the dBase packages alone.

Much of the credit for the company's expansion strategy belongs to its new management team, headed by president Edward Esber, Jr., who stepped into the top position after cofounder and CEO David Cole departed last summer. Esber says he intends to expand the company's product line by adding artificial intelligence features to existing programs and customizing software for particular market segments. Several software start-ups with which Esber has been involved are also rumored to be acquisition targets, including Lightyear (a maker of "decision support" programs), and Palladin Software (which took over some of the staff and products of the defunct VisiCorp). Ashton-Tate should start seeing results even without acquiring additional R&D troops, says VP Posner, in the three to five new products—some developed internally—it hopes to announce by year's end. ***—Mary Jo Foley***

CompuSonics:
BRINGING DIGITAL RECORDING HOME

Digitally recorded music, with its clean, precise tonal quality, is causing the first upheaval in the audio industry since the introduction of stereo. In fact, sales of compact disc players are one of the few bright spots in the otherwise flat market for audio gear. But the high-priced recording machines that etch tiny pits onto master laser discs (which are then used to manufacture commercial copies) weren't designed for the consumer market. Thus audiophiles, musicians, and amateur recording buffs have had to content

themselves with the still-slim library of prerecorded music.

Now, CompuSonics, a small Denver company, is developing a microprocessor-based system to record digital audio on the kind of magnetic floppy disks ordinarily used to store computer data. It expects to price the DSP-1000 recorder and player at about $1500—the high end of the price range for consumer equipment. The company manages to use the relatively small storage capacity of floppy disks to record tonally complex music by combining its software with a Texas Instruments signal-processing chip. The system analyzes and compresses audio data in real time, so that by analyzing the software model of, say, a long flute note or a moment of silence, it can record the sounds in abbreviated form. (In contrast, compact discs, with their vastly greater storage capacity, record the entire audio data stream.) Company VP John Stautner, who is a member of MIT's experimental music studio in Cambridge, Mass., says his staff's best efforts have produced a data reduction ratio of 16 to 1, although a 4-to-1 ratio is more common for most music.

However, even with data compression, the current system can record only about 3½ minutes of music on a floppy disk. The time can be lengthened to CompuSonics' goal of 45 minutes (equivalent to that of most record albums) only when higher-density floppy disks and drives become commercially available. Several companies are experimenting with high-density floppies, including Kodak's Spin Physics and Verbatim divisions and Maxell. "We can already get floppies capable of supplying more bits than a hard disk," says CompuSonics founder and president David Schwartz.

But critics contend that prototype disks available now are a long way from being mass-produced. George Plotkin, an MIT research fellow in audiology, says that "CompuSonics doesn't have a chance" if it expects to get high-quality floppy disks with the storage capacity necessary for recording music. Schwartz himself admits having problems obtaining the disk drives that can read high-density floppies. "There's just no demand yet," he says, "so no one makes the drive head." As a result, the company may have to resort to building its own drive.

Even if CompuSonics manages to overcome its hardware problems, skeptics question whether the system's potential market is big enough to be worth the effort. The DSP-1000 will be too expensive for most consumers, contends Robert Heenan, president of Q Audio (Cambridge, Mass.), an audio and video retailer. And other observers point out that tiny CompuSonics may soon face formidable competition in digital audio recording. Several Japanese companies are experimenting with recently introduced 8mm videotape as a medium for recording digital music.

Undaunted, CompuSonics insists it will introduce the DSP-1000 this fall—with or without the increased floppy disk capacity it hopes to achieve. For support of its products, CompuSonics has been spending lavishly on advertising. It has managed to attract interest from Japanese electronics companies Sansui and Nissho Electronics for manufacturing components and distributing the DSP-1000 in Japan and from the West German company Siemens for manufacturing and distribution in parts of Europe.

CompuSonics realizes it must work much harder to break into the consumer market than it did to enter the professional recording market last fall with the DSP-1000's forerunner, an elaborate multitrack digital audio mixer and recorder (priced at about $35,000) that uses a hard disk for storage. But it is hoping that its early start will be a major asset in overcoming its problems.—***Theresa Engstrom***

CompuSonics president David Schwartz demonstrates a prototype of the DSP-1000, a consumer version of the company's studio-quality digital music recorder.

Thermedics:
RACING TO DEVELOP AN ARTIFICIAL HEART

In a set of pioneering medical experiments, the Jarvik-7 artificial heart gave William Schroeder and Murray Haydon a new lease on life. But because they had to remain tethered to cumbersome air-driven support systems, this new lease was highly restrictive.

There is hope, however, that artificial-heart patients will be living more comfortably by 1990. Thermedics (Woburn, Mass.) and several other small companies are racing to develop hearts that are driven electronically, powered with small portable batteries rather

than with air pressure. Although Thermedics faces strong competition, led by Symbion (maker of the Jarvik-7 heart), the potential rewards are well worth fighting for: "There's probably a $100 million market or better out there," says John Ball, a security analyst with Paine Webber Mitchell Hutchins.

Unlike an air-driven device, an electronic heart could be implanted in the body without dangling tubes or wires. The Thermedics device is powered by a holster-like underarm battery pack that extends from chest to waist. The system has "no penetrations," says company vice-president Victor L. Poirier. Instead, a coil attached to the battery pack and strapped to a patient's stomach transmits power through the skin via a high-frequency radio transformer. For swimming or bathing, a patient can remove the pack, letting an internal battery pack a mere three inches in diameter take over (it can work for several hours).

Vice-president Victor L. Poirier holds Thermedics' completely implantable artificial heart.

The Thermedics heart also differs from the Jarvik-7 in that it's a "ventricular-assist device," working in tandem with a patient's own heart rather than replacing it. A one-inch-square microchip, part of the internal battery pack, monitors the natural heart and synchronizes the pumping of the artificial heart. The device's pump can replace the function of either of the natural heart's two main chambers; two pumps can duplicate both.

Ball at Paine Webber estimates that the Thermedics heart is at least two years away from being a commercial, FDA-approved product. But he predicts that the heart's "quite extraordinary" engineering, especially the design features that let patients detach their battery packs, will keep Thermedics in the forefront of the artificial-heart race.

Thermedics' Poirier expects the struggle for market leadership to be hard-fought. "What you're going to see in the next five years," he says, "is a horse race, with several groups taking market share." He predicts that the competition will soon include large corporations, either because they have acquired one of the small pioneers or because they have formed a joint venture. In fact, his company is talking to a number of major firms about joint ventures, even while fortifying itself financially (it made its second stock offering in May, raising close to $4.4 million).

The events of the next few years will be the culmination of 19 years of research conducted by Thermedics and its parent firm, Thermo Electron based in Waltham, Mass. The National Heart, Lung, and Blood Institute made Thermedics its leading grant recipient for artificial heart R&D funds, which led to the development of an air-powered heart-assist pump that, like the Jarvik-7, is run by a computerized air compressor. Between 1975 and 1982, such pumps were implanted in 43 patients for five or six days while they underwent transplants or other heart surgery. But Thermedics decided against bringing this pump to market, opting instead to develop the implantable electronic heart.

The company's first commercial product is a pliable polyurethane material, called Tecoflex, that it uses to make its artificial-heart bladders. Sales of the material, which can also be used in artificial arteries, small catheters, and pacemaker leads, generated over $500,000 in 1984. This year, Thermedics also began selling Spandra, a polyurethane bandage that simulates skin by transmitting oxygen, carbon dioxide, and water vapor. And it is testing a related product, Skin Button, for use as an infection-resistant long-term conduit for patients who have to be fed intravenously, who use kidney dialysis machines, or who suffer from urinary problems.

But the company's main efforts will focus on bringing its artificial heart to market. Thermedics estimates that 100,000 patients compete each year for the 1500 to 2000 biological hearts available for transplants. For as many as 35,000 of these people, according to a study published earlier this year by the National Institutes of Health, the development of fully implantable, permanent artificial hearts could be the key to resuming a comparatively normal life. ***—Elizabeth Willson***

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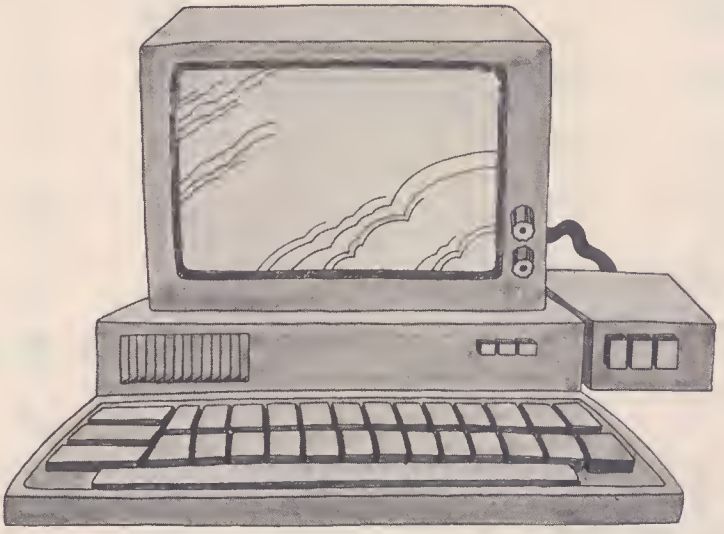

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Vice-president Victor L. Poirier holds Thermedics' completely implantable artificial heart.

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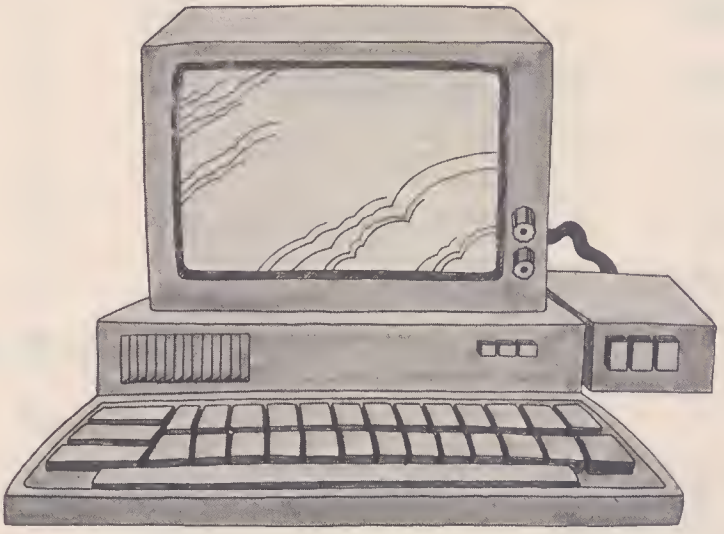

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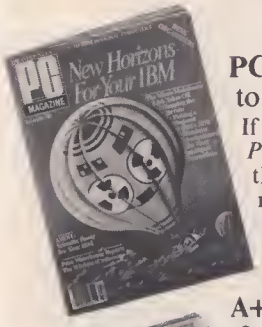

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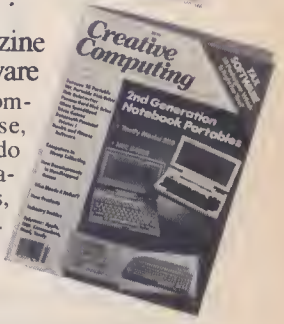

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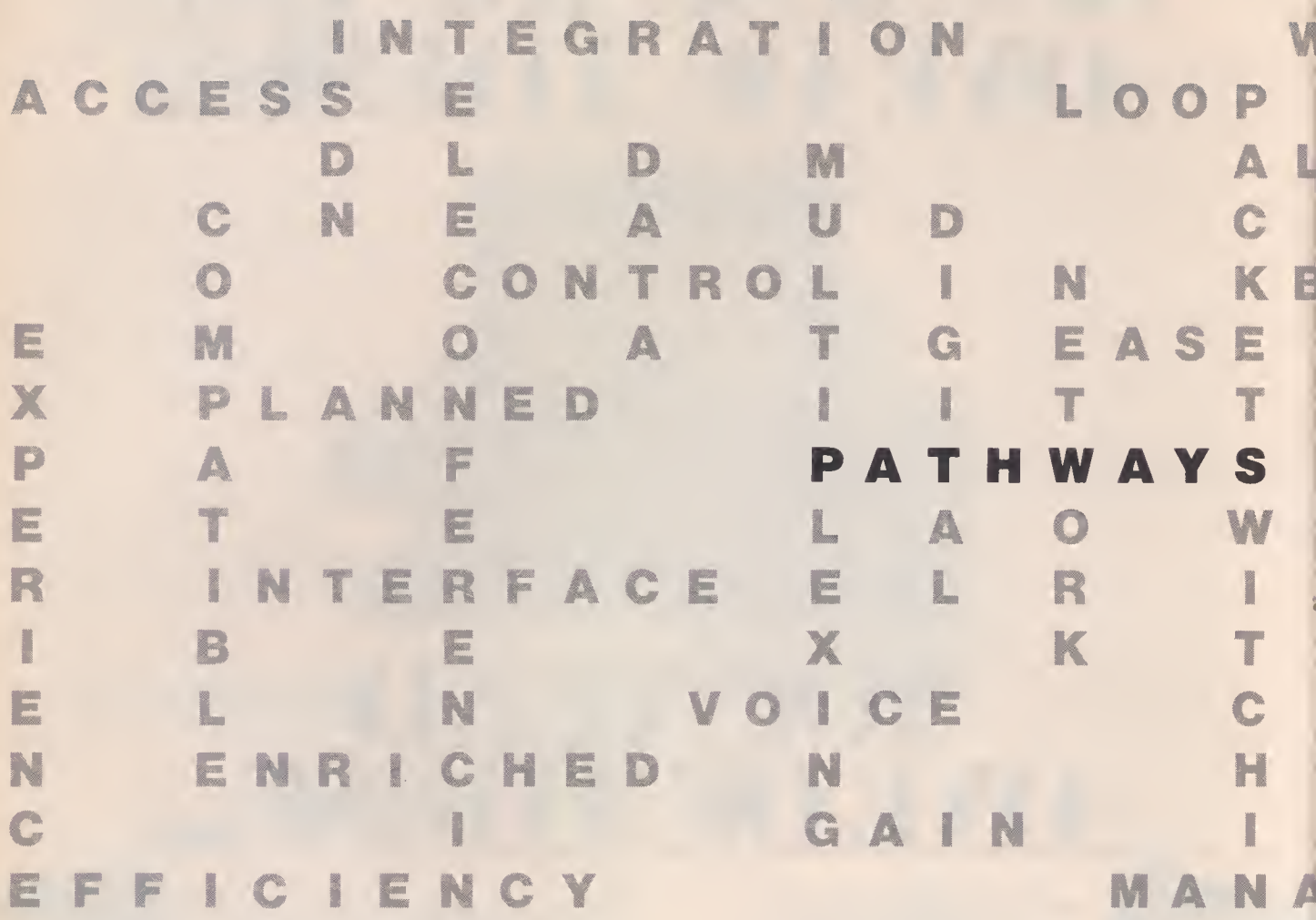

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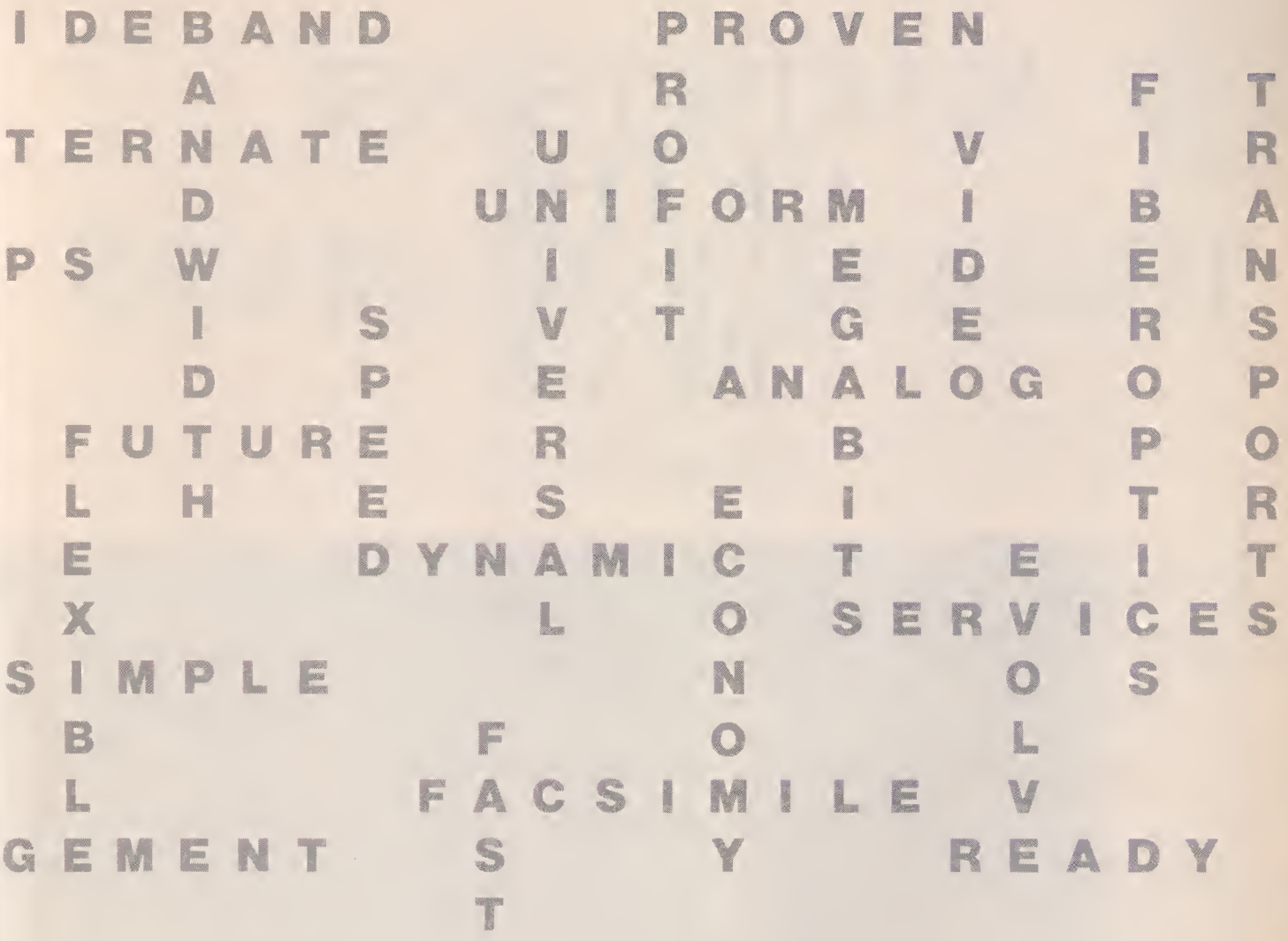

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MAKING SENSE OF THE TELECOMMUNICATIONS CIRCUS

by Dwight B. Davis

It's been 20 months since AT&T's telecommunications monopoly was splintered by a federal consent decree, and some business customers are still virtually paralyzed with confusion. The divestiture's goal of bringing competition into a single-vendor marketplace has succeeded almost too well: Companies are being bombarded by so many service and product options from so many vendors that they are beginning to feel like spectators at a three-ring circus.

But in the midst of this chaotic scene, some of the major telecommunications providers have begun to rally around a common vision of the future. Central to this vision is a digital network that relies heavily on sophisticated switching equipment and on the prodigious transmission capacities of fiber optic links. AT&T, the 22 now-independent Bell operating companies (BOCs), and other telecommunications vendors foresee a day—possibly as soon as the mid-1990s—when virtually all voice, data, and video signals will travel over a unified digital network. Others are more cautious in their predictions of how quickly such an integrated network can be achieved, but most vendors are scrambling to establish positions that will allow them to exploit this technology when it arrives. Communications users, meanwhile, are attempting to make purchasing decisions today that will not only meet their current needs but also make the transition to any future network as inexpensive and painless as possible.

As users come to terms with the post-divestiture marketplace, they are discovering new ways to cut communications costs and to improve the quality and speed of both voice and data transmissions. The best solution varies from company to company, but there are so many options that solutions can virtually be tailored to suit individual needs. Many large corporations are installing their own networks, and even the smaller firms have several "bypass" options open to them by which they can send transmissions over routes other than the traditional public phone network. Companies are realizing, too, that there must be a smooth connection between their in-house communications systems and the external networks they access. Ensuring that company-based communications equipment is compatible with today's and tomorrow's outside networks is a key concern of both users and suppliers.

Divestiture has brought a confusing array of products and services, but vendors are rapidly converging on common goals

Driving technologies. Even prior to AT&T's divestiture, the telecommunications arena was witness to some far-reaching technological innovations, and the pace of change has since accelerated. Most notable is the shift from wavelike analog to digital transmission, which consists of discrete pulses. AT&T began installing its "T-carrier" digital links as long ago as the early 1960s, and they now carry about 40% of AT&T's long-distance transmissions. In contrast, most local phone links are still analog, but these too are gradually being replaced by digital connections. Much of the digital capacity being installed is fiber optic cable, which provides very reliable transmission and supports a huge amount of traffic. A typical fiber optic cable consists of 144 glass fibers, each no thicker than a human hair yet able to support over 4000 voice channels.

Regardless of the transmission medium, digital cable links offer a number of advantages over analog. One of the most important is an improved error rate: about 1 in 10^7 for digital, versus 1 in 10^5 for "dial-up" analog (the temporary connections that are established when we call into the phone network) and about 1 in 10^6 for specially conditioned "leased" analog lines (which a company rents for its exclusive use). Analog's reliability suffers because its signals must be boosted by amplifiers that can't distinguish between the actual signal and any noise on the line, resulting in an increased error rate. Rather than being amplified, digital signals are simply regenerated when they pass through network nodes.

Although analog's error rates are acceptable for voice traffic, they are often too high for reliable data transmission. Today data transmission accounts for only about 5–15% of the traffic carried by the phone network, but its share is increasing. "Data traffic is growing at a rate of 30–35% per year, while voice traffic is growing at only about 6–8%," says Fritz Ringling, VP of the Gartner Group's Strategies in Telecommunications Service (Greenwich, Conn.). He expects that data will constitute 40% of the telecommunications traffic by the 1990s. This shift is providing much of

the impetus to convert the telecommunications network to high-reliability digital connections.

Aside from their drawback of relatively high error rates, analog lines also provide only limited speeds for data transmissions. Because the local phone lines leaving office buildings are still analog, the bulk of today's data transmissions must first be converted to analog waves by modems (modulator/demodulators). The fastest modems capable of sending reliable data traffic over dial-up lines operate at 2400 bits per second (bps), although several vendors expect to introduce 9600-bps dial-up modems in the near future. Higher-quality analog leased lines can support modems operating at up to 19,200 bps.

Companies that require reliable, high-speed data links today have several digital options open to them. A common solution is to lease digital links from the local and long-distance phone companies. AT&T Communications, for example, offers a family of digital services under the Accunet label. These range from Dataphone digital services (DDSs), operating at 2400 bps to 56 kilobits per second (kbps), to data and video transmission services, which operate at 1.544 megabits per second (commonly known as the T1 rate). Alternately, companies can install their own digital transmission links, bypassing part or all of the public phone network.

The increasing digitalization of networks—both public and private—is fueling a movement to integrate the transmission of computer data with digitized voice (and eventually video). This trend is already well underway within offices, thanks to the availability of digital PBX (private branch exchange) switches that support both voice and data traffic. But while few dispute the trend, many believe that its main proponents so far are vendors, not customers. In fact, one of the most common criticisms of the free-for-all market that has followed divestiture is that too many of the new products and services are being driven by technology instead of market need. "There's an awful lot of technological showmanship going on out there," says Bob McGeary, director of marketing for wide-area net-

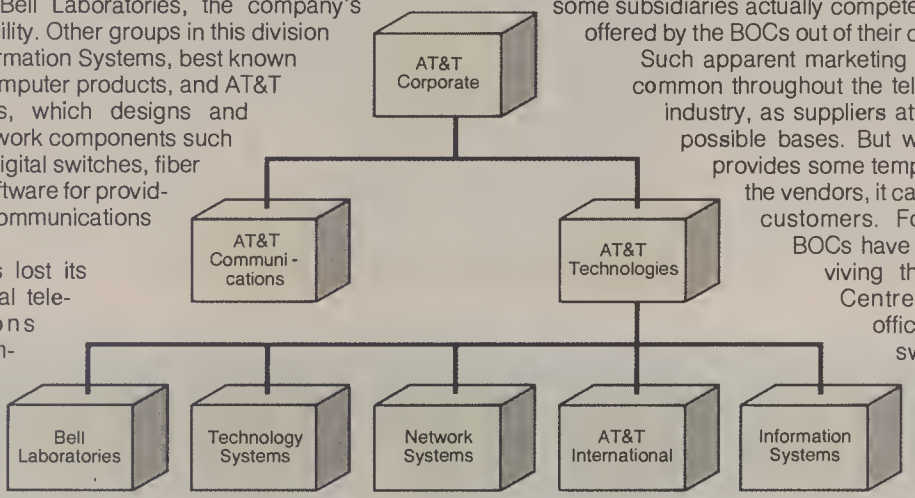
PETER VIDOR

AT&T's Villiere examines the massive 5ESS switch, the company's hope for leading the market into digital networks and integrated voice, data, and video transmissions.

AT&T: divided but not conquered

With its divestiture in January 1984, the once monolithic AT&T was segmented into diverse, and sometimes competing, divisions. Divestiture's major achievement was to break the local Bell operating companies (BOCs) away from AT&T's long-distance operation. Within AT&T, the two divisions beneath AT&T Corporate are AT&T Communications, the firm's regulated, long-distance arm, and AT&T Technologies, the company's equipment branch.

Several groups fall under the AT&T Technologies umbrella, including Bell Laboratories, the company's influential R&D facility. Other groups in this division include AT&T Information Systems, best known for its PBX and computer products, and AT&T Network Systems, which designs and manufactures network components such as sophisticated digital switches, fiber optic links, and software for providing advanced communications services.



Although it has lost its control of the local telecommunications links, AT&T Communications retains about 85% of the long-distance market. MCI Communications and GTE Sprint come in a distant second and third. They and the other common carriers depend upon various mixtures of their own transmission facilities and lines leased from AT&T for their long-distance capacity. In AT&T's case, the transmission links are a combination of terrestrial copper cable, microwave, satellite, and, increasingly, fiber optic cable.

AT&T's telecommunications equipment branch, Network Systems, depends heavily on its sister AT&T Communications and the BOCs for its business. But while Network Systems has obvious family ties with these customers, they are all willing and able to shop around for the products they want from any supplier that can provide them. "The Bell operating companies now have a lot of selection and a lot of people knocking on their doors," says Paul Villiere, Network Systems' executive VP for marketing and customer operations.

AT&T's former holdings are now divided among seven regional companies that operate the BOCs as well as a number of other subsidiaries. These subsidiaries are involved in a smorgasbord of businesses, including the publication of the Yellow Pages and the sale of customer-based computer and communications equipment. In the latter activity, some subsidiaries actually compete with the services offered by the BOCs out of their central offices.

Such apparent marketing conflicts are now common throughout the telecommunications industry, as suppliers attempt to cover all possible bases. But while this situation provides some temporary security for the vendors, it can be unsettling for customers. For example, the BOCs have succeeded in reviving the once flagging Centrex, a central office–based phone-switching service. Meanwhile, the parent regional holding companies are selling customer-based PBX equipment. "You wonder sometimes what is the real thrust of the telephone companies' strategy," says Fritz Ringling, VP of the Gartner Group's Strategies in Telecommunications Service.

Errol Unikel, manager of market operations at AT&T Network Systems, says that the company's present strategy is to make a profit by selling its telecommunications equipment either to the telephone companies or to individual corporate customers. "We can make money in either the private or the public sector," he says, "but we think that in the future it will be more economical for everybody to get services from the public sector."

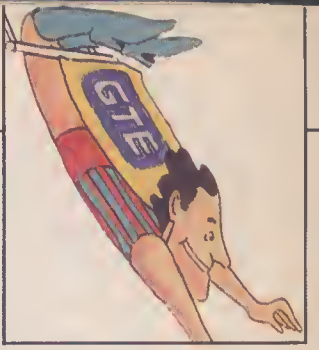
work products at Concord Data Systems (Waltham, Mass.).

The marketplace witnessing these activities is one considerably more fragmented than was the case prior to divestiture. The federal consent decree divided the country into more than 160 local access and transport areas (LATAs); the BOCs and other local telephone companies are restricted to transmissions inside their own LATA. Moreover, each independent company has its own area of operation within the LATA. As a result, the local phone companies don't compete with one another for customers, but they do try to distinguish themselves with new products and services in order to increase their share of the limited investment pool, notes a spokesperson for BOC Illinois Bell.

When a customer makes a phone call or transmits computer data over the dial-up network, the signal travels to the nearest "central office" of the local phone company. If the call destination is within the same area (a non-toll call), that office will switch it directly to the recipient. Small phone companies may have to send a signal to the central office of a larger phone company (probably a BOC) to connect some toll calls within the LATA. For calls to points outside the LATA, local phone companies must access the facilities of an "interexchange" carrier (such as AT&T Communications), even if they have central offices in adjacent LATAs. The interexchange carriers have one or more "points of presence" in each LATA they serve.

The move to bypass. The segmentation of the telecommunications world into distinct local and long-distance operations has contributed to a trend known as bypass. The local phone companies now collect access charges from any long-distance carriers with points of presence in the LATA; the FCC has determined that this fee adds about 8¢ per minute to the cost of a long-distance phone call. Coupled with uncertainty about future rate changes and unhappiness with the limitations of local analog links, the access fee is causing some companies to establish digital links to bypass parts of the public telecommunications network.

Bypass can take several forms (see chart, p. 25). The most common approach—"service bypass"—involves sidestepping the local analog links by leasing digital T1 links from the local phone company. Although the phone company owns these links, which connect the user's facility to an interexchange carrier's point of presence, leasing them can reduce costs because the interexchange carrier pays no access charge on them and the links can reliably support both voice and high-speed data transmissions. The demand for T1 links has become so great that one of



the hottest telecommunications products today is the T1 multiplexer, a device that mixes and routes digital data over one or more T1 channels.

Still, a T1 link from the local phone company costs $1000–$1500 per month to lease, so many companies can justify "facility bypass"—circumventing the local carrier entirely—says Robert P. Bernardi, chairman and CEO of Spectrum Digital (Herndon, Va.). His company and others sell microwave radio equipment that allows a customer to establish a direct digital link (which can include several T1 channels) to an interexchange carrier's point of presence. Although it costs about $25,000 to buy and install such a microwave link, says Bernardi, the expense can be cost-justified against a single T1 link given a two-year payback period. "If you need two or more T1 links, you definitely should put in microwave," he says. Bernardi estimates that for every 10 companies that set up T1 private networks, seven lease T1 lines through the local phone company and three install microwave equipment.

Microwave is a common option for facility bypass, because no companies have the right-of-way to install terrestrial cables. (Cable TV operators can provide bypass via their installed coaxial cable, but they have been slow to enter this market.) And although microwave offers error rates of as low as 1 in 10^{10} to 1 in 10^{12}, says Bernardi, it does have some drawbacks. One is the need for a clear "line of sight" between the two end points. Another is the tendency for rain and snow to interfere with transmissions at frequencies higher than 11 gigahertz, but this susceptibility can be taken into account when the equipment is installed. "There are curves that show you what distance you can go with microwave given the rainfall typical in a particular area," Bernardi explains. "If you want 99.99% availability of an 18-GHz microwave system in Phoenix, you can probably transmit about 14–15-miles. If you want that level of service in Houston, where it rains quite frequently, you might go only 5–6 miles."

Beyond the facility bypass of the local loop, companies can opt for "total bypass," or bypass of the entire phone network. This typically involves setting up satellite links between different company locations. However, while satellite routes are acceptable for data transmissions, echoing and delay problems (which result from the time required for a signal to travel to and from a satellite) make this method a marginal solution for voice traffic. And while satellite transmissions are typically more cost-effective than terrestrial links over long distances, fiber optics will reduce this advantage.

Concord Data Systems' McGeary: "Digital transmission will catch on very quickly at large companies, but small to medium-sized companies won't be able to afford it for some time. So analog is going to be around for a while."

Gaining network control. Aside from the speed and error-rate benefits inherent in digital transmissions, one of the key reasons a user might opt for bypass would be to have control over the network links—control that has traditionally been relinquished to the local and long-distance carriers. Before divestiture, customers couldn't independently reconfigure the network to meet changing demands. They had to rely on the carriers to fix problems that might develop, such as line degradations that cause increased error rates, and service wasn't always as dependable as some customers would have wished.

As the strategic importance of communications has grown, and as market confusion about the effects of divestiture has increased, a number of companies have made moves away from the public carriers. Establishing and maintaining reliable voice and data links has become such a priority for many firms, says Richard Amster, director of data communications research at the Yankee Group (Boston), that "the people making network buying decisions are putting their careers on the line."

This situation has proved beneficial to vendors like RCA Cylix (Memphis) that operate private data networks. "Once companies discovered how much they had to be cognizant of and how much they had to manage," says Ron Young, VP of marketing, "a lot said, 'Gee, I've got to find someone to do all of this for me.' "

Likewise for vendors in the "build-your-own" camp. "Divestiture was great for us," says Arthur Caisse, president of start-up Cohesive Network (Campbell, Cal.). "Corporate America realized it had to get more involved in running its own networks." Cohesive markets a communications switching node that lets companies set up and run networks incorporating a wide range of transmission media and services.

Bearing the brunt of the bypass phenomenon are the local phone companies. To combat the trend, local carriers that are powerful enough—namely the BOCs—are investing heavily in equipment and services intended to keep the large corporate customers in their fold. The BOCs' main tactic is to offer expanded central office services, including some that give customers more direct control in establishing and reconfiguring public network communications links. The BOCs are also offering more competitive rates and are beginning to give customers pricing contracts that guarantee a fixed rate for an extended period.

Intraoffice communications. The BOCs aren't spending all their time fighting bypass brushfires, however. They are also attempting to take business away from two groups—the PBX and the local-area network (LAN) vendors—that are already in fierce competition for the intraoffice communications equipment market.

These two groups started in separate niches, but the confluence of voice and data has eroded the wall between them. PBX systems are well established as intraoffice telephone switches that provide a variety of functions, such as call forwarding, and give callers access to outside phone lines. LANs appeared a few years ago in order to permit data communications networks among a company's computers within a limited geographic area. The two types of systems rarely crossed, unless the LAN interfaced to the PBX to gain access to the outside world.

As digital PBXs supporting data as well as voice transmissions began to appear, however, each camp started pointing out the shortcomings of the other's products. LAN vendors, whose systems typically carried data at speeds of 1–10 million bits per second (Mbps), sneered at the more limited bandwidth capabilities of the PBXs. In response, the PBX vendors claimed they would not only eventually match the LANs' speeds but also enable an integrated voice/data future that would leave the data-oriented LANs behind.

The data-carrying capacity of PBXs *is* growing substantially, but it's still an open question whether such systems will be able to cost-effectively meet both voice-switching needs and the extremely high data transmission requirements of such networked computer applications as computer-aided design and computer-aided engineering. As is often the case with such battles, neither side is likely to emerge a clear winner, at least not for some time. "We're no longer talking about PBXs and LANs as an either/or option," says Jeff Kaplan, a senior marketing analyst at International Data Corp. (Framingham, Mass.). "Both of them are needed to meet an organization's internal and external communications needs."

BOCs play both sides. Given their telephone orientation, the BOCs naturally tend to favor PBXs in the intraoffice networking debate. But they're not really choosing sides: They want to take business away from the PBX and the LAN vendors alike. A flagship offering of the BOCs has long been the Centrex service, which the telephone companies use to provide customers with simple phone switching out of the central offices. Various vendors are now offering the BOCs advanced Centrex functions that make the service more competitive with the feature-laden PBXs. (Interestingly, most of the BOCs have subsidiaries that sell PBX equipment to those companies that shy away from Centrex. Likewise, while AT&T Network Systems is among the suppliers of advanced Centrex capabilities to the local phone companies, AT&T Information Systems is busy trying to sell customer-based PBXs.)

Aside from its growing list of features, Centrex offers some economic advantages over PBXs. "With Centrex, you don't have the up-front expense you have when acquiring a PBX," says Kaplan. "In addition, the incremental charges for upgrading the capacity of the Centrex service is not as great as it would be for a PBX." On the other hand, he notes, "companies that can withstand the capital investment of buying a PBX get an investment tax credit and the payback of being able to depreciate the equipment."

BOCs are now targeting LANs as well as PBXs. They are marketing alternative services based on systems such as the Datakit Virtual Circuit Switch, developed by AT&T Network Systems. Located in the central office, the Datakit system provides LAN-type data switching and transmission to subscribers in the same way that Centrex provides voice PBX features. Bell of Pennsylvania (Philadelphia) recently installed the first Datakit, which will provide LAN-like services to West Chester University (West Chester, Pa.)

While LAN vendors "definitely are concerned" about such competition, says Martin Goldberg, director of LAN marketing at Codex (Mansfield, Mass.), the cloud has a silver lining. "Having the BOCs in the market helps make the world more aware that LANs are here and that they do solve problems."

In addition to intraoffice communications, the BOCs are also finding new opportunities to offer services now associated only with a group of long-distance data communications suppliers called value-added networks (VANs). For years, these specialized private data networks have offered data transmission services beyond those provided by long-distance common carriers such as AT&T Communications. By regulation, common carriers offer little more than basic transmission capacity—voice and data channels and switches that route signals to their intended destinations. VANs, which may own or

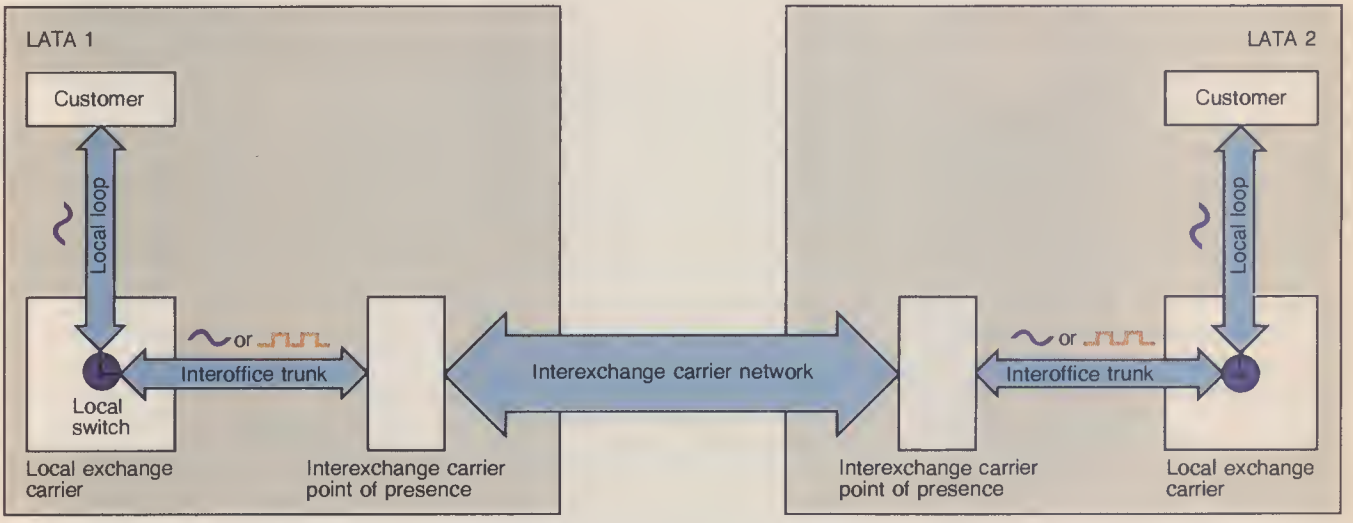
lease the transmission links over which they operate, incorporate intelligent switches to provide additional services to customers with specialized data communications needs. Typical VAN offerings include electronic mail, industry-specific communications applications, and speed, code, and protocol conversion of data traffic.

VANs typically fill the niche between the small data communications user that can get by with simple, dial-up analog lines, and the large corporate user that requires its own dedicated communications lines. In addition, some VAN suppliers compete in the latter arena, selling scaled-down versions of their networks for private use by large corporations. These networks consist of much the same hardware and software found in the VANs' public networks, but they are set up to link a single company's distributed offices. "More than 50% of the private data networks sold in the United States in 1984 came from us," claims A. S. Rajaraman, director of network planning for Tymnet (Cupertino, Cal.), a leading VAN operator owned by McDonnell Douglas. He says most of those buyers still maintain links to the Tymnet VAN, which can handle any "overflow" data during the peak hours and can provide network control features that may not be present in the user's network.

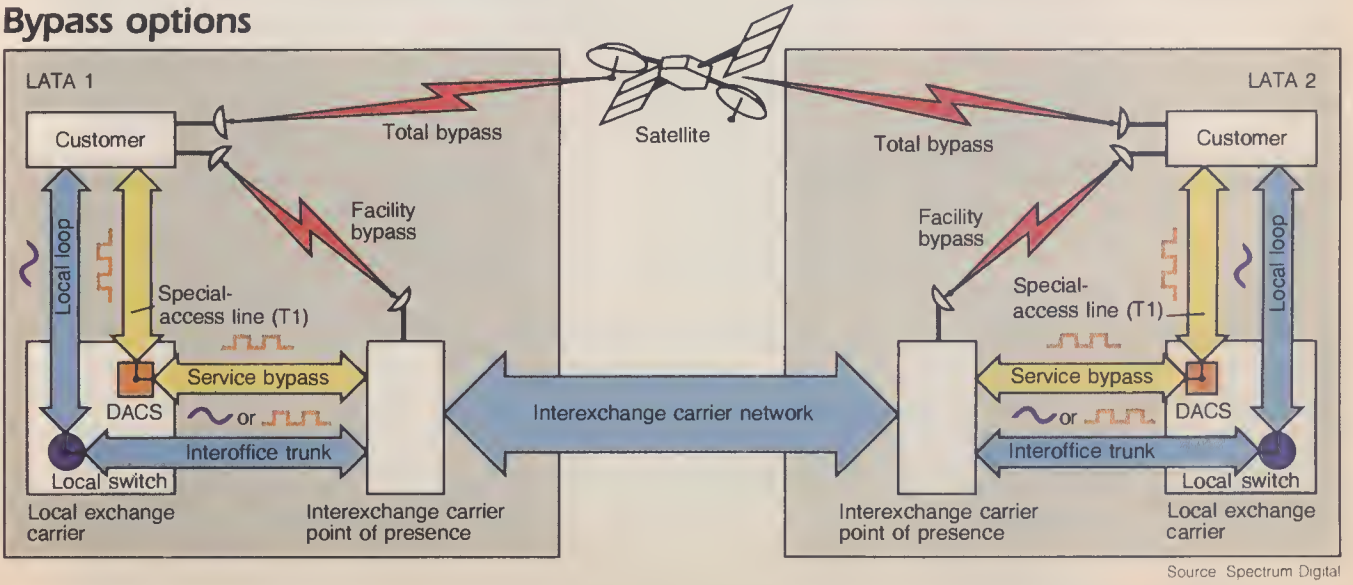
While they offer a wide variety of services, the special attraction of VANs is the method by which most transmit their data: via packet switching. Long messages are broken into several packets (which also contain routing, sequence, and error correction information) for transmission, and packets from many users' messages can be in-

Companies sending large amounts of voice and data communications traffic are constrained by the analog links between their sites and the local phone company. Also, they must bear the cost of access fees that the long-distance interexchange carriers must pay for the right to have facilities (points of presence) within each local access and transport area (LATA). To avoid these drawbacks, customers have several options. They can lease high-speed digital T1 links from the phone company—links that carry no access fees. They can bypass the local phone company by setting up a digital microwave link between themselves and the interexchange carrier. Or they can establish satellite links to avoid the public phone network entirely.

Traditional switched access



Bypass options



Source Spectrum Digital

Blurring technological distinctions

As communications networks become increasingly digital and carry growing proportions of data traffic, the distinctions between data processing and data communications are beginning to blur. Communications is now an integral part of the computer world, where links must be established between the various machines that have proliferated. Meanwhile, communications networks themselves have become increasingly intelligent. To network nodes that once merely switched and routed voice and data traffic, companies are adding computer hardware and software that perform processing functions such as speed and protocol conversions to allow distant or dissimilar machines to communicate.

Because data processing and data communications are both lucrative, high-growth markets, the technological blurring between them has encouraged vendors to migrate from one area to the other. In a 1980 ruling known as Computer Inquiry II, the Federal Communications Commission permitted AT&T (through subsidiaries separate from its operational arm) to enter the computer marketplace, from which it had previously been barred. Although its offerings have yet to pose major threats to the established computer manufacturers, the company's financial might and technological know-how (centered in Bell Laboratories) should bolster its long-term viability as a computer vendor.

Computer giant IBM, likewise unwilling to ignore huge market opportunities, is moving aggressively into the communications business. The company already owns Rolm (Santa Clara, Cal.), second only to AT&T as a U.S. supplier of office PBX systems. And in June, IBM strengthened its position in the long-distance telephone business by establishing an alliance (pending FCC approval) with the number-two carrier, MCI Communications.

Surprisingly, AT&T Communications has welcomed the IBM/MCI deal, believing that with IBM putting its muscle behind MCI, AT&T will have a stronger case in petitioning the FCC to remove restrictions that still bind it. "This announcement should put to rest any remaining questions about the strength of the competition in the telecommunications business," said Randall L. Tobias, chairman and CEO of AT&T Communications, following the IBM/MCI announcement. He cited the agreement as "further proof that sophisticated investors are being attracted to this business, and that there is now scant reason for maintaining regulatory restraints imposed on AT&T even before the divestiture."

termixed over a single line. This procedure is particularly useful for data transmissions that are "bursty," such as interaction between a remote terminal and a mainframe computer. Between message bursts, ordinary communications links lie idle, but packet networks exploit this unused capacity by filling the line with data packets from a number of bursty sources.

Packet data networks are popular worldwide, thanks largely to a (somewhat flexible) standard that defines the interface between computer or terminal equipment and the packet network. The standard, X.25, was promulgated by an international telecommunications standards body, the CCITT (International Telegraph and Telephone Consultative Committee).

This year the local BOCs got permission to provide packet switching, protocol conversion, and other VAN-type services. Under the terms of a 1980 (predivestiture) FCC document known as Computer Inquiry II, the telephone companies could offer such "enhanced" data services only through independent subsidiaries. The restriction aimed to prevent the BOCs from cross-subsidizing the costs of enhanced services with revenue from their "basic" operations, which, because of their guaranteed rate of return, would have given them an unfair market advantage. Several BOCs had long petitioned the FCC to drop this restriction, which they considered outdated and unfair, and last March they got much of what they wanted: The FCC voted unanimously to remove most of the barriers preventing local phone companies from directly offering their customers packet-switching service.

Despite the FCC's promise to closely monitor against cross-subsidization, some existing packet-switched VANs were dismayed by the ruling. But at least one BOC planning to implement such service—Illinois Bell (Chicago)—claims that it won't take business away from the long-haul packet networks. "Just as we provide the local access for voice communications into the interconnect carriers," says Ron Czaplewski, product manager of digital business services, "we're looking to provide the same kind of local interface with the packet interconnect carriers such as GTE Telenet and Tymnet." Some VANs agree with this perspective, and believe that their business will actually improve as the BOCs entice more customers into the packet-switched world. Some of these new customers, it is reasoned, will have to turn to VANs to meet their requirements for long-distance packet transmissions.

Fully integrated future. Along with its move toward local packet switching, Illinois Bell will soon embark on the first U.S. trial of a much ballyhooed service known as Integrated Services Digital Network (ISDN). In the minds of its proponents—most notably AT&T and the BOCs—ISDN represents a major step toward realizing the plugged-in information society that has been promised by visionaries since the dawn of the computer age.

The key feature of ISDN is that it provides for integrated voice and data access to an all-digital network. This access might even occur through a common interface similar to the familiar RJ-11 telephone jack, which lets us plug any phone into any standard wall outlet. New terminals—for voice, data, or both—would be built to conform to the ISDN interface; older equipment could attach to the network through specially developed adapters.

Like X.25, the ISDN standard is under the auspices of CCITT. It is meant to become a worldwide standard for integrated access; AT&T has endorsed the concept and says it will abide by the still-developing CCITT recommendations. The evolving ISDN is being tailored to mesh smoothly with the distinct digital networks that already operate around the world. In the U.S., then, the standard's "primary," or high-capacity-bandwidth, interface will conform to the existing 1.544-Mbps T1 standard. And in Europe, it will conform to the existing 2.048-Mbps standard. Special nodes linking different countries' networks will transparently handle the conversion necessary to move information from one network to another. Common to all regions may be the 144-kbps "basic" rate, which would serve the needs of most residences and small to medium-sized businesses.

Unlike the existing U.S. telecommunications network, the ISDN separates the "message" information from the signaling (routing and control) information. ISDN provides for two types of channels: 64-kbps "B" channels for voice and data traffic, and 16- or 64-kbps "D" channels, which carry signaling and low-speed packet data. By moving the signaling data "out of band," ISDN frees the full B channel for carry-

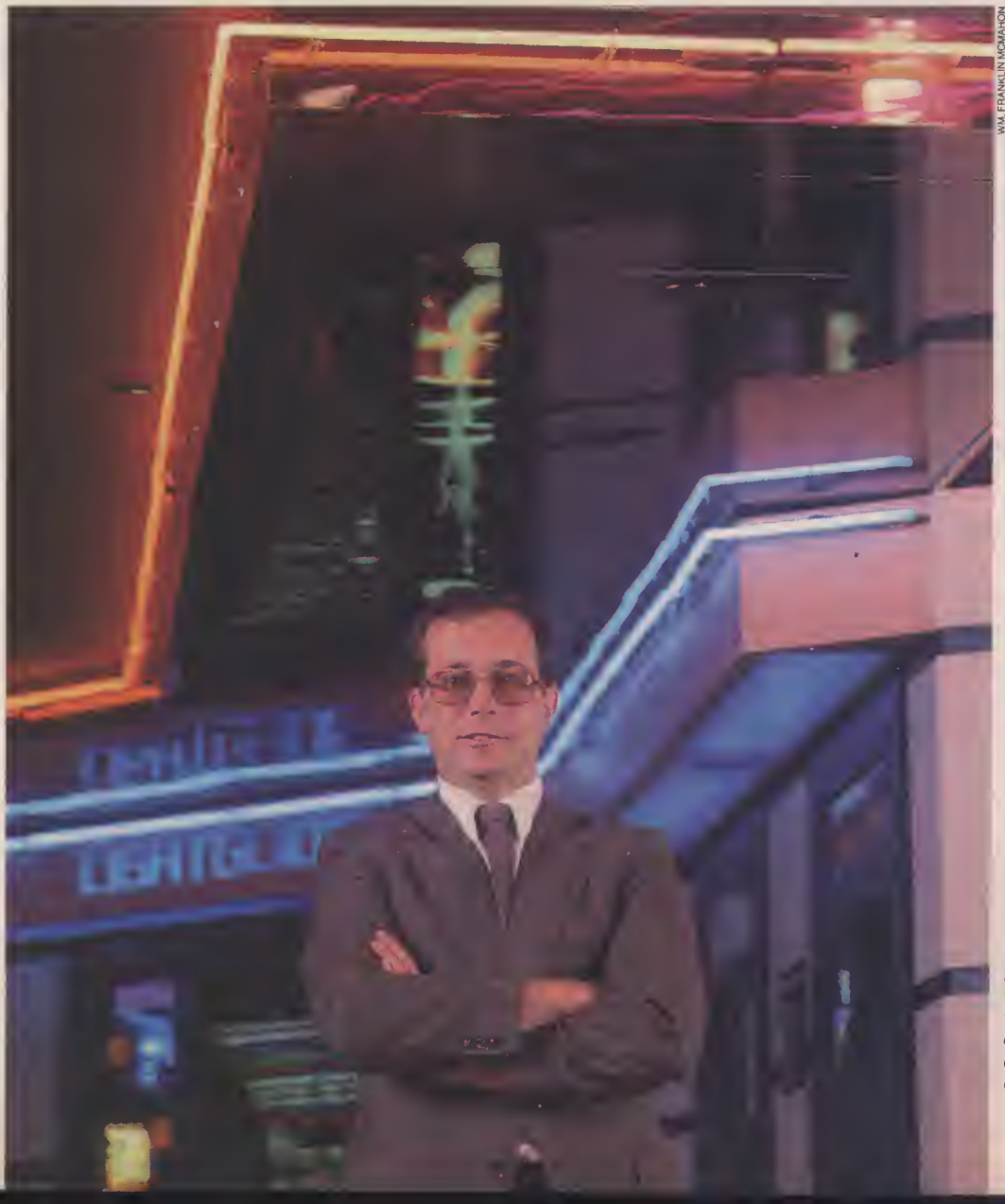
ing message information. (With "in-band" signaling, one out of every eight bits is used for signaling information, leaving only 56 kbps of a 64-kbps line available for message information.)

In the U.S., companies that require T1-level links would acquire one or more primary interfaces, each consisting of 23 B channels and a 64-kbps D channel, yielding an aggregate rate of 1.536 Mbps. (The extra bits available over the 1.544-Mbps links are used for message framing, error checking, and other housekeeping chores.) Individual voice/data terminals and residential users would typically access a basic interface that consisted of two B channels and a 16-kbps D channel to achieve the target 144 kbps.

In Illinois Bell's three- to six-month ISDN trial, beginning in the fourth quarter of 1986, the corporate offices of the McDonald's fast-food chain will be provided with integrated voice and data access to the digital service. The trial will be supported at the BOC's central office by an AT&T Network Systems 5ESS (electronic switching system) running ISDN software. Movement toward ISDN will accelerate as soon as the first trials are over, predicts Paul Villiere, AT&T Network Systems' executive VP for marketing and customer operations. "The boom years will be 1987 and 1988," he says.

Others are more reserved in their predictions. H. Paris Burstyn, an analyst with Arthur D. Little's World Telecommunications Information Program (Cambridge, Mass.), thinks ISDN will arrive quickly only if its "Services" part includes enough useful applications—such as automatic credit-card verification and retail shopping via data terminals—to attract a wide range of customers. Burstyn also points out that ISDN can't exist without underlying digital network interfaces, switches, and channels, and he questions whether such an extensive infrastructure can be built as quickly as AT&T and other companies seem to believe.

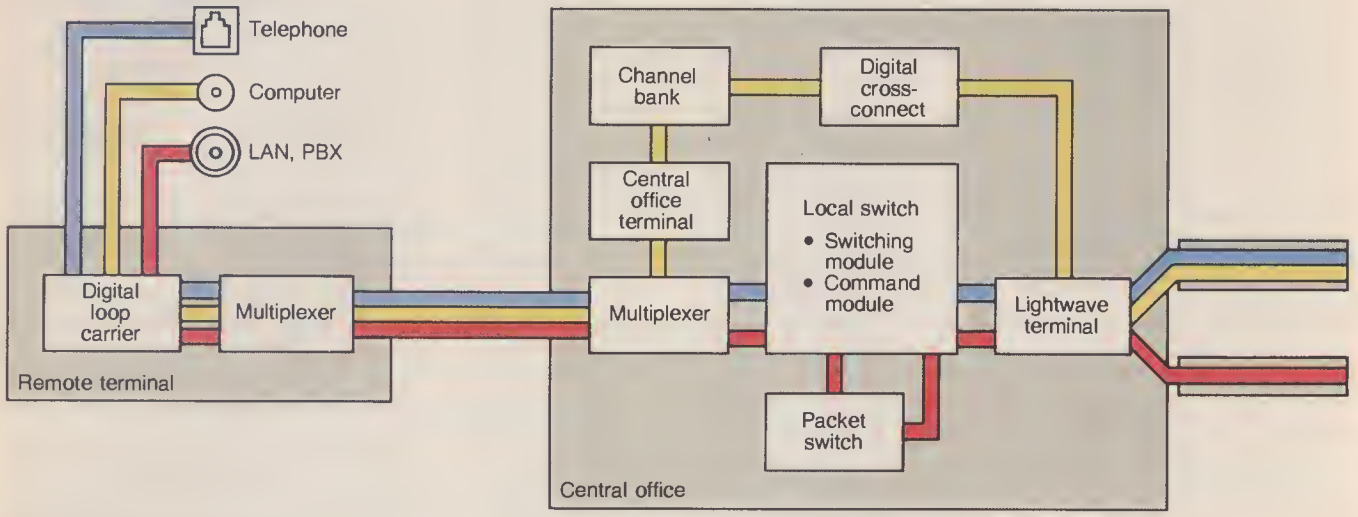
Noting that the BOCs will be reluctant to scrap their billions of dollars worth of central office equipment and local analog lines, Concord Data Systems' McGeary says that "it will be a minimum of 10 years before the phone companies put in new equipment that can accept either digital or analog." Of course, his company and every other modem vendor have good reason to



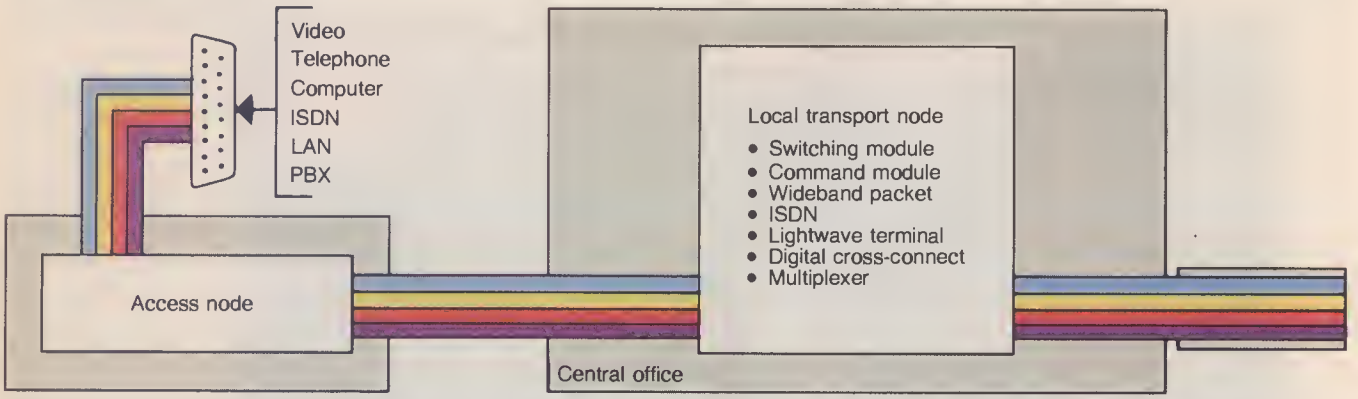
WM. FRANKLIN MCMAHON

Some say that new telecommunications technologies are solutions in search of a problem, but Illinois Bell's Czaplewski says that the installation of digital networking capacity and services is being driven by the demands of business customers.

1985 architecture



1990s architecture



With today's telephone network, different types of voice and data equipment access the system through a variety of interfaces. The different signals are combined by a remote terminal onto a common link for transmission to the local phone company's central office, where they are handled separately. Data traffic, for instance, passes through a central office terminal, which can change analog signals to digital, then through a channel bank, which combines several low-speed channels into a high-speed composite channel, and then through a digital cross-connect unit, which connects different carriers' digital channels.

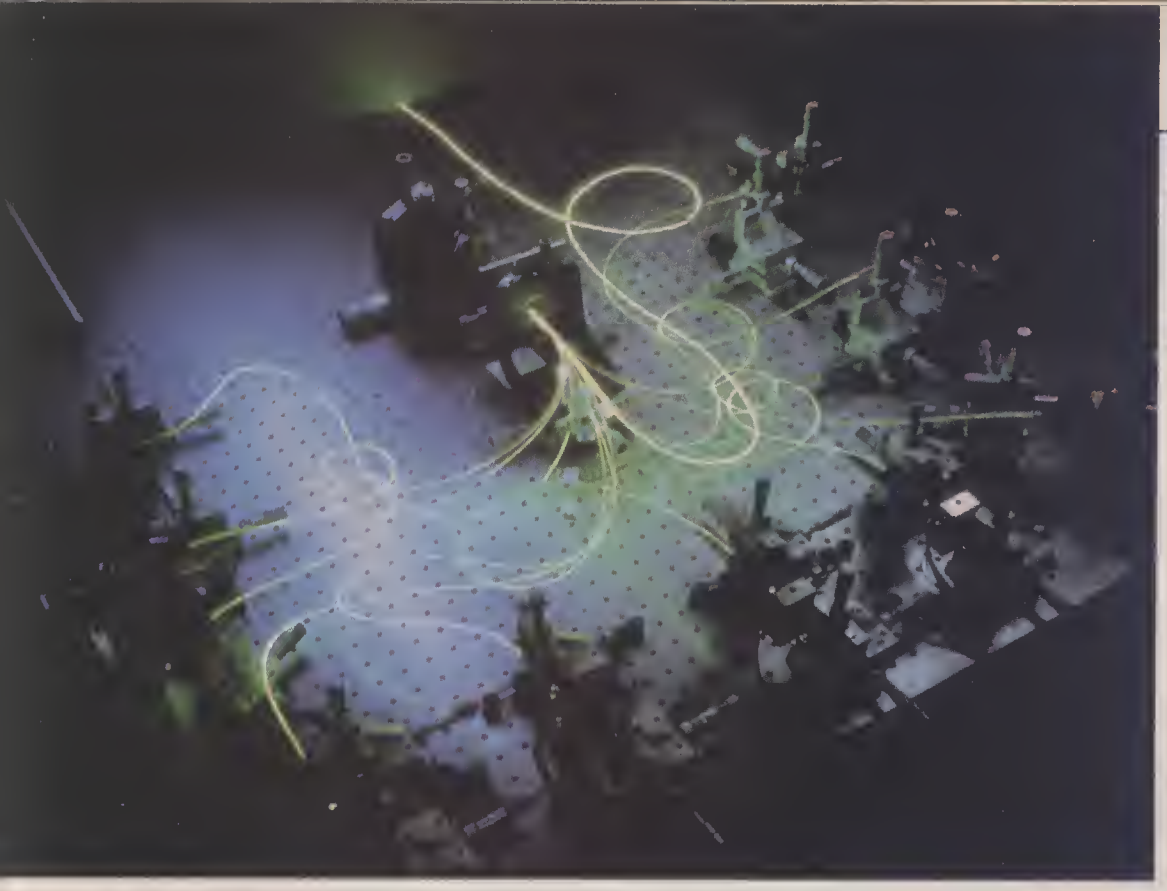
By the 1990s, AT&T believes all types of transmissions, including video, may access the network through a universal port, and will be merged onto a common digital medium—typically fiber optic—for routing. The central office equipment will become much more integrated, with a single, sophisticated switch performing all of the tasks now handled by a variety of equipment.

hope that ISDN won't arrive too quickly: Devices that convert digital data to and from analog waves have no place in a fully digital network. But McGeary says that Concord Data and other modem manufacturers see the writing on the wall. "It's really the *rapidity* of the migration to digital that's up for debate," he says. And as the digital communications world develops, he predicts, the modem will evolve into a more sophisticated box—a "communications processor"—that performs advanced functions such as protocol conversion, data compression, and encryption.

Ironically, although divestiture has accelerated the move toward network digitalization, it has also provided short-term help for one segment of the modem industry: the booming field of 2400-bps modems that operate over dial-up lines. As the phone companies struggled to adjust to divestiture, the waiting time for leased lines slipped to six months or longer. Many of the customers put on hold for these conditioned lines turned to 2400-bps modems, which gave them higher-speed dial-up communications than was previously possible.

As if ISDN and its vision of integrated voice and data access to high-speed digital networks weren't sweeping enough, AT&T has let it be known that ISDN is just a step toward the *real* future of the telecommunications industry, the Universal Information Service (UIS). This system would transmit video as well as voice and data—entered through a standard wall interface—over a single digital network. Such "integrated transport" would rely upon wideband packet-switched networks that have far greater capacities than the packet networks of today, and upon the gradual conversion of the terrestrial network to fiber optic links.

AT&T claims that UIS not only would integrate the transport of different types of communications traffic but also would give customers considerable control over the organization of their links within the public network. And because customers would be billed only for services used, as opposed to paying standard rates for prearranged capacity and services, Villiere maintains that UIS will reverse the corporate trend toward building private capacity.



An experimental multiplexer at Bell Laboratories can combine the lightwave signals from 10 lasers onto a single optical fiber that carries 20 billion bits of information per second.

Corporate dilemma. For businesses now trying to make intelligent communications purchases, talk of revolutionary new networks a few years off can be unnerving. Still, some savvy vendors are trying to sell products on their adaptability. "Customers are concerned, and are willing to pay a premium if you can really demonstrate that you have a powerful architecture that will comply with future changes," says Dietrich Arbenz, VP of Marketing and Sales for the Office Systems Group of Siemens Communications Systems (Boca Raton, Fla.).

At the very least, companies should ensure that the equipment they buy today conforms to accepted standards, says McGeary at Concord Data Systems. "The company that ignores standards may find out a little too late that its equipment doesn't work in certain environments," he warns. Of course, determining the one "true" standard in a market segment that may have dozens isn't always that simple. Until some consensus is achieved, many companies choose to purchase equipment from major suppliers such as AT&T and IBM, on the assumption that these firms' products set de facto standards.

Although standards will continue to prove troublesome, some aspects of the telecommunications environment have begun to improve as a result of divestiture. The increased competition is causing formerly inflexible parts of the public network to become attuned to the market's demands. "No one felt very comfortable using the old Bell operating companies, because they were bureaucratic, unresponsive entities," says IDC's Kaplan. "But now they've been forced to become more sensitive to user needs, and the issue of user control may, as a result, be diminished."

Also, while ISDN and UIS may loom on the horizon, most vendors agree that the all-digital public network won't arrive for at least five years. Because the payback period for investing in new equipment can be relatively short, it makes sense for many companies to go ahead with such purchases, argues Spectrum Digital's Bernardi. "The payback for setting up a private network and for such products as T1 multiplexers is well under a year," he says. "So the time horizon for investing in these solutions is outstanding, especially since people are faced with problems today."

IDC's Kaplan agrees, noting that the full-blown services to be offered by BOCs for intraoffice communications won't be available for at least three to five years. If a company is frustrated in the options now available from a BOC's central office, "then it's probably in the company's best interests to buy a PBX and a LAN," he says. "Three to five years is a good payback period for anything you buy today."

While companies should attempt to buy industry-standard equipment whenever possible, they needn't be overly concerned that future public network offerings will make new purchases obsolete. "It's a basic objective of the service providers to support already installed equipment because their customers have made such a major investment," says ADL's Burstyn.

This view is even shared by the once imperial AT&T, which realizes it can't ask businesses to make a clean break with the past. "With our ISDN offering we will support every kind of terminal available today," says Errol Unikel, manager of market operations at AT&T Network Systems. "We have to let the customer get used to ISDN without having to junk all his existing equipment."

A good portion of preparing for the new networks, though, rests on the shoulders of the customers, who must carefully evaluate their existing and future communications needs. "If you don't first define your requirements," says Burstyn, "you can't ask the right questions of the suppliers, and you won't get the right answers."

Fortunately, one of the main effects of divestiture has been to force customers, willing or not, to become more savvy about communications issues. "Consumers are saying, 'Wait a minute. What do I really need?' " says Concord Data Systems' McGeary. "The market is becoming a lot more intelligent." □

Dwight B. Davis is a senior editor of HIGH TECHNOLOGY.

For further information see **RESOURCES** *on page 69.*

BUSINESS OUTLOOK

Data services add features to networks

A rising star in the telecommunications firmament is the value-added network (VAN), which piggybacks on top of basic transmission a range of services that include packet switching, optimal routing of data, error detection and correction, speed and protocol conversion, and customized applications. The VAN market should reach $310 million this year and should climb to a hefty $1.5 billion by 1988, according to the Yankee Group, a market research firm in Boston.

The VAN market is currently dominated by three firms: GTE Telenet Communications (Vienna, Va.) is the largest player, with a 32% market share; Tymnet-McDonnell Douglas Network Systems (San Jose) commands 27% of the market; and United Telecommunications (Lenexa, Kans.) has a 13% share. Other players include Automatic Data Processing (Ann Arbor, Mich.), CompuServe Network Services (Columbus, Ohio), and RCA Cylix Communications Network (Memphis). Over the past two years, three entrants with deep pockets have also joined the fray: AT&T Information Systems (Morristown, N.J.), IBM (Tampa, Fla.), and GE Information Services (Rockville, Md.).

"VAN vendors have been playing a big waiting game, making capital investments and accepting low immediate returns in anticipation of the day when a mature VAN market will explode."

Brian NeSmith, Communications Consultant, Network Strategies

As recently as 1980, timesharing and access to public databases were the major uses made of VANs. But "the largest market segment now encompasses intracorporate communications in such areas as database management, order entry, inventory, payroll, and price lists," says Clint DeGabrielle, vice-president of marketing and field operations at Tymnet. Personal computers in homes and offices can also use VANs to send electronic messages, or to tap into the database and transactional services—including banking, shopping, and travel planning—offered by information utilities such as Dow Jones News/Retrieval, CompuServe, and The Source.

"VAN companies compete with each other more on the extent and quality of their geographic coverage, network management, and industry-specific applications than on the basis of cost," says Claudia Houston, manager of public affairs at GTE Telenet. In this spirit, Telenet provides its own electronic mail service and has joined the American Medical Association in establishing diagnostic databases for physicians. IBM has set up a VAN that serves the insurance industry, and United Telecommunications facilitates Control Data's Travelhost reservation system.

Profits proved elusive for most VAN companies throughout the 1970s, in part because of the capitalization costs of network building. By the early 1980s, however, VANs were positioned to take advantage of a growing need for long-distance connections between terminals and an increasing variety of databases, electronic message services, and transaction services. "With average charges of $6 an hour—based on usage, not distance—VANs are cost-effective compared with the primary public alternatives: WATS lines, which typically cost $20–$25 an hour, and direct distance dialing, at $25–$30 an hour," says Peter Winther, director of new communications services at Link Resources (New York).

At present, there is competition for VANs from two sources: very large corporations and the regional Bell operating companies (BOCs). Some firms with heavy communications needs employ their own private VANs, and those with excess VAN capacity may even be tempted to start their own public services as independent profit centers. But VAN vendors prefer to see this as a business opportunity; Tymnet alone has installed 38 private networks for major companies.

The impact of regional Bell companies on VAN leaders is less clear. Last March the Federal Communications Commission permitted the BOCs to save on expenses by colocating packet-switching and protocol conversion services with their central-office telephone equipment. Link's Winther points out that this government decision could enable the BOCs to provide basic VAN services for as little as $2 an hour, and hence to compete effectively with national VAN vendors for the business of information providers.

However, there are some restrictions on BOC activities. Service is limited to the operating areas of each phone company. The allowable protocol conversions are limited to interfacing terminals with mainframe databases and corporate communications networks, using an older, though still widely employed, protocol format. And additional enhanced services can be made available only through fully independent subsidiaries. Thus, says Winther, "there are a lot of terminals out there that would need protocol conversions that the BOCs can't touch under their regulated services."

Clint DeGabrielle, VP, Marketing, Tymnet

"Opportunities for VANs will grow as personal computers become commonplace and more business functions are automated, triggering the widespread exchange of electronic data."

In any case, Tymnet's DeGabrielle maintains that "VAN firms are not standing still in their search for new applications." Downloading of instructions to robots, electronic funds transfer, and management of building energy systems are some of the more recent innovative uses of VANs. "Ultimately," says DeGabrielle, "VANs may provide the backbone of the cashless, paperless information society."

—Dennis Livingston

GIVING ROBOT HANDS A HUMAN TOUCH

Mechanical fingers with a variety of sensors can provide versatility and dexterity

At MIT, a three-fingered robot hand flips a tiny cylinder with the ease of a human hand.

PHOTOGRAPHS BY MARTY FAUL

The human hand is a truly marvelous tool—an integration of dexterity, sensitivity, and strength that many designers of robots hope to emulate. But although science fiction writers give their robots anthropomorphic hands without a second thought, to actually build them is a formidable challenge. "Lots of long-term research is needed before robot hands become practical," says Warren Seering, professor of mechanical engineering at MIT. Better sensors and control algorithms, he points out, are especially critical. They are being pursued in research programs at several university laboratories—where progress is slow, but steady and promising.

While Seering questions the general appropriateness and cost-effectiveness of building humanoid features into industrial robots, he does see opportunities for dexterous hands in some types of com-

by Daniel V. Edson

mercial applications. In fact, he predicts that such devices could be working in industry by the end of this decade. Already, companies such as IBM, General Electric, and General Motors are studying robot hands for precision assembly of delicate mechanical and electronic components. A robot hand built at the University of Utah can perform such delicate tasks as turning a wing nut or cracking and beating eggs, and can even play some tunes on the piano.

MIT researchers are working on a three-digit device called the Stanford/JPL hand, designed by project leader Kenneth Salisbury, who did graduate work at Stanford, and Carl Ruoff, a Jet Propulsion Laboratory researcher. In its present form, it simply grips objects and makes minor movements, but higher-level programming will allow more complicated manipulation. The hand's thumb and two fingers are modular; Salisbury says a fourth digit could be added for more complex tasks. "To continuously rotate an object," he explains, "the hand would keep three digits in contact with an object while repositioning the fourth."

A robot hand at the University of Utah already has four digits, one of them a dissimilar, opposing thumb. Each finger has four joints, and the thumb has three. Moving so many fingers is no simple matter: It requires 32 high-strength Kevlar and Dacron tendon belts, driven by 32 tiny pneumatic actuators bunched in the forearm.

Known as the Utah/MIT hand, the device is a collaborative effort between the University of Utah Center for Biomedical Design and the MIT Artificial Intelligence Laboratory. Stephen Jacobsen at Utah, the chief designer, oversees mechanical design, and MIT researcher John Hollerbach directs the computer programming. The ambitious goal of the project, says Jacobson, is to "produce a hand that exhibits performance levels roughly equivalent to the natural human hand."

While the MIT and Utah researchers have concentrated on robot hands with humanlike fingers and a wide range of motion, work in progress at the University of Pennsylvania Robotics Laboratory aims to control a simpler hand by touch-sensor input. The three-fingered hand determines an object's shape with conductive rubber sensors on the last joint of each finger. It can perform elementary manipulations such as holding an object with two fingers and pushing it with the third. But in its current configuration, it does not have the potential dexterity of the Stanford/JPL or Utah/MIT hands.

By the time any of these U.S. projects reaches commercialization, dexterous hands from Japan might well have beaten them to the punch. According to James Albus, chief of the robot systems division at the National Bureau of Standards (NBS), the Japanese have probably built a greater number of articulated grippers than anyone else in the world. Most are still in the research stage, however.

The leading dexterous hand project in Japan today is a three-fingered model under development by Hitachi (HIGH TECHNOLOGY, March 1985, p. 80). Unlike the Pennsylvania, Stanford/JPL, and Utah/MIT hands, whose fingers are moved by electric motors and pneumatic actuators, Hitachi's uses a memory-metal actuator to pull the wires that move the four joints in each finger. When heated by an electric current, the stretched nickel/titanium actuator wires shrink to their original length, pulling the wires connected to the joint. When the heat source is turned off, the wires relax and a spring returns the joint to an extended position.

Robot fingers may soon be equipped with high-precision tactile sensors that produce a digital image of manipulated objects just as human fingers can determine unfamiliar sizes, shapes and orientation by physical touch.

Although memory-metal actuators have been used before in dexterous hands, Hitachi has improved on them by using a bundle of very thin wires, which can be heated quickly, rather than one relatively thick wire, which was slow to heat, delaying response time. The Hitachi design has definite drawbacks (not the least of which is sluggish return because the wires cool more slowly than they heat), but the memory-metal actuators produce a lighter and more compact hand.

While dexterous hands constitute the leading edge of robot gripper research, work is also proceeding on more conventional parallel-jaw grippers. As a result, they are becoming more sophisticated, embodying capabilities such as tactile sensing and undertaking high-precision tasks such as electronic assembly.

Engineers at the University of Rhode Island (URI) Robotics Center, for example, are testing a gripper that represents an important compromise in dexterity, cost, and reliability between standard, low-cost grippers and robot hands. Mechanisms built into the gripper halves can move an object up, down, around or sideways. Although the gripper cannot offer the finger movements of a robot hand or pick up as wide a variety of parts, it is adept at grasping cylindrical objects and rotating them quickly between its jaws.

On the flat inner surface of each jaw is a rotating platform on which is mounted a translating belt. Around each platform is a pneumatically actuated ring that can be elevated and retracted. Two optical sensors are located on each ring. Extensions, known as retractable fingernails, slide out from the end of each jaw to help guide an object within the gripper.

The development of dexterous hands is currently based largely in academia because it is still speculative and long-term. Most of the work in the U.S. is funded by the government—particularly the Department of Defense—which will probably shape early applications. Robot manufacturers and industrial users are studying dexterous hands but not yet investing in them.

General Motors, a company already heavily invested in robotic technology and active in robot system design, is cautious. "The articulated hand is on the back burner," says Richard Beecher, manager of robotics at GM's Technical Center in Warren, Mich. But "we have a very active development program underway for a parallel-jaw gripper that is fully instrumented. Right now, that's a whole lot closer."

Nonetheless, many robotics specialists consider dexterous hands part of a natural evolution in robot design. And although their cost and complexity will restrict their use, these multipurpose hands will endow robots with a number of important and generally applicable features. The most obvious benefit of such devices is their ability to handle many object sizes, shapes, and orientations—one after another—either under pure software control or by responding to feedback from tactile sensors.

In contrast, handling an assortment of parts with conventional grippers, which can assume only limited configurations, requires mechanical innovation, such as customizing end-effectors with more than one gripper, changing end-effectors, or even using more than one robot arm, each with a different gripper. These schemes work, but they can be costly and slow. And they run contrary to a basic precept of robotics: to change software, not hardware.

At the University of Utah, a robot hand can delicately crack an egg (above), drop the contents into a bowl, and whip them (right) many times faster than a skilled chef. Commercial grippers can already handle some delicate tasks, such as assembling ordnance (far right, above) at an Aerojet factory in Tustin, Cal. MIT researcher Kenneth Salisbury (far right, below) predicts that the more versatile robot hands will see significant commercial use for precise tasks in three to five years.

DANIEL EDSON (RIGHT AND ABOVE)

LOU JONES

Gripper firms get a handle on robot markets

International Data Corporation (IDC—Framingham, Mass.) estimates the U.S. robot market at $320 million this year, growing at 20–30% annually to $975 million by 1990. "Robot hands compose a small proportion of this total," says William Tanner, director of engineering at ORS Automation (Troy, Mich.). Annual sales of material-handling and assembly end-effectors will grow over the next five years, he predicts, toward the $30–40 million range.

While most robot arms used in this country are imported under license from Japan and Europe, end-effectors are manufactured primarily by domestic firms, many of which are small machine shops whose customers are local robot users. Only a few companies manufacture end-effectors for national distribution. These include Barry Wright (Watertown, Mass.), Lord (Cary, N.C.), Monforte Robotics (Trenton, N.J.), Pneumatic Hydraulic Development (Fort Wayne, Ind.), Mecanotron (Minneapolis), Mack (Flagstaff, Ariz.), and Applied Robotics (Latham, N.Y.). Barry Wright and Lord also make tactile sensors—which enable grippers to develop pressure images of objects being grasped—while Applied Robotics specializes in end-effectors that permit tools to be exchanged quickly during a work cycle.

So far, there is no generic design for hands. Thus vendors serve as original equipment manufacturers whose products must undergo additional customization and integration with robot arms. Such systems work must be performed at both ends of the hand. At the wrist end, an adapter—a mechanical interface—is required to attach the hand to the robot, because bolt patterns on a hand may not match those located on the wrists of different robot brands. At the tool end, the jaws or fingers of a gripper must be tailored to handle the size and shape of the various parts and tools it will encounter.

Vendors have responded by offering families of hands that are useful across a range of applications and by taking on custom jobs whose results might be applied elsewhere. Nevertheless, "the market for end-effectors is relatively limited, and profits are elusive," says Don Wood, vice-president for marketing at Pneumatic Hydraulic Development. "As with some of the other vendors, end-effectors are an adjunct to our other product lines."

But there is ample room for growth in this arena. For one thing, "touch sensors will significantly increase the application of end-effectors in assembly operations by enabling robot hands to put together more delicate parts with higher accuracy," says Peter Cholakis, product manager at Barry Wright. And the Robot Industries Association is attempting to standardize wrist bolt patterns. "With such standards," says ORS's Tanner, "an end-effector could be attached directly onto the wrists of robots from different manufacturers, eliminating the need for hand adapters. That could create more business for vendors from robot users who presently customize everything from the wrist down."

End-effector markets will also be expanded by the spread of robots from painting, welding, and material-handling applications into assembly operations. "The fastest-growing application sector is in picking, fitting, and transferring small parts for mechanical and electronic assembly," says Peter A. Cohen, research manager of the computer integrated manufacturing service at IDC. "Assembly tasks will increase from a 10% market share in 1984 to 25% by 1990."

Most important is the potential shift of robots from operations characterized by repetitive, high-volume runs of single products—where hands are dedicated to specific manufacturing functions and do not need to be reconfigured—to relatively small production runs. Up to 75% of U.S. products are manufactured in such batch processes.

ORS's Tanner believes that business opportunities will soon open for vendors producing equipment such as quick tool exchangers, multipurpose hands, and "smart" grippers with integrated force and pressure sensors—devices that can cope with the rapid changes in parts and tooling inherent to batch operations. "Ultimately," he says, "dexterous multidigit analogs to human hands will take over a substantial portion of all assembly tasks."

—Dennis Livingston

"A robot can perform only the functions its hands can carry out. Adaptable, easy-to-reconfigure end-effectors will thus extend the robot's flexibility and expand its applications."

Mathew Monforte
President
Monforte Robotics

Articulated hands bring another important benefit to robotics: precise positioning. With a manipulating hand, minute movement and final positioning are done by the fingers; in a conventional robot with an end-effector capable only of gripping and releasing, all movement of the object—whether coarse or fine—must be accomplished by the arm or wrist. A robot arm designed for spatial movement through a working radius of a couple of feet is also required to make precise final positioning moves of a fraction of an inch. That's a lot like putting the cap on a pen without using your fingers.

But to successfully incorporate the features of flexibility, precision, repeatability, speed, and ease of use into commercial robots requires more R&D and a tremendous amount of design work—in pursuit of improved hardware and control software alike. "Related to the need for better hands is the requirement for better actuators and motors," says URI engineer William Palm. "And how do you use all the information from visual, tactile, force, and position sensors?"

The stringent programming requirements stem from the high levels of redundant movement in the hands—their multiple "degrees of freedom." In human hands the tendon, muscle, and nerve systems for movement demand the attention of a large portion of the brain: Commands to tendons, for example, must take into account the effect on other joints and subsequent friction in the system. Thus MIT's Hollerbach points out that development of robot hands will require a sophisticated understanding of the human nervous system. The devices will not reach their full potential until control algorithms are devised to complete the control loop between sensor and hand motion.

Sensors themselves remain a major stumbling block to robot hand development. Like other robot grippers, dexterous hands can use a variety of sensors: position, proximity, force, and vision. But to be truly effective, they must have the sense of touch that is afforded by tactile sensors. These devices, made from such materials as conductive rubber, piezoelectrics, phototransistors, and displacement transducers, can be used both for force control—by supplying feedback on grip pressure—and for pattern recognition.

Force control mainly requires the ability to produce continuous pressure readings (in contrast to pressure measurement in more elementary grippers, which simply indicates whether a threshold has been reached). Pattern recognition is more complex. At the Battelle Institute (Columbus, Ohio), for example, researchers have designed a piezoelectric sensor that could be used to determine the location of an object or even to produce an image of it. When the sensor touches an object, different pressures are produced in different places, just as the human finger feels points, edges, holes, and other surface and texture qualities. These pressure levels, which have better resolution than the human finger, are used to produce a digitized image of the object, which is analyzed to determine such information as size, shape, and orientation.

EDWARD J. SPERKO/ GM

General Motors' Richard Beecher is cautious about using robot hands for industrial applications. Instead, he says, the company is developing a fully instrumented parallel-jaw gripper that meets its current needs more closely than an articulated hand.

As researchers begin to find solutions to the problems of sensing and control, robot hands will start to move out of university labs and into the industrial arena. Indeed, the Stanford/JPL hand was designed for retrofit applications. MIT's Salisbury believes that it could be commercialized in three to five years and that some of its sensors and software may be put to industrial use even sooner.

Similarly, even though commercialization of the Utah/MIT hand is not expected for as long as a decade, Hollerbach says parts of the design, such as the actuators or tendons, might find earlier application. And he adds that because of NASA's interest in high-performance dexterous hands, the Utah/MIT hand might first be used in the space program.

Meanwhile, the need for multipurpose manipulators in general and those with dexterous fingers in particular is being debated in both industry and academia. One argument against robot hands is simply cost versus function. Compared with simple grippers or custom end-effectors, dexterous hands will be expensive, even in wide use. A question often asked is, why build a hand that can accommodate parts of different shapes and sizes if the factory of the future is supposed to contain no disordered parts? And some robotics specialists suggest that trying to imitate human fingers would at best institutionalize the limitations of the hand and at worst be a futile quest.

"Criticism comes from both sides," says Utah researcher Edwin Iversen. "Some feel that multipurpose functionality is not important—that specialty end-effectors should be custom built—while others feel that if you are going to make it multipurpose, why emulate the hand?"

Whether or not they are modeled after the human hand, NBS's Albus believes that multipurpose grippers can coexist with specialized ones. "I don't see coalescing of one [approach] or the other," he says. "Both should grow and prosper. There are good economic reasons to go in both directions." □

Daniel V. Edson is a freelance technology writer in Rowley, Mass.

For further information see **RESOURCES** *on page 69.*

"VAX IS GIVING AMF MORE TIME FOR THE THINGS THAT REALLY MATTER."

Michael Lilly
Director, Corporate MIS/Operations
AMF, Incorporated

To many people AMF means recreational sports. But today it also means electronic components, filtration equipment, automated process equipment and more.

It's a vastly more complex company. A company made vastly more manageable by Digital's VAX™ computers – the vital component of office automation at AMF Corporate/MIS Operations.

As Michael Lilly says, the company's decision to stake its future in MIS on Digital's VAX computers – and the office automation tools like ALL-IN-1,™ DECnet™ and DECmail™ software that run on them – was hardly a snap judgment.

Every major computer company was considered. Lilly says that, "dollar for dollar," only Digital's VAX system offered the power, ease of use and communications capability with other computer systems – including IBM – that AMF needed.

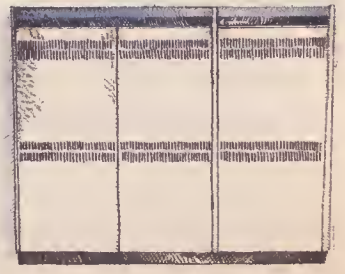
So AMF chose the VAX computer – the best-selling 32-bit computer in the world – and waited to see what the machine could do.

"SUDDENLY WE HAVE TOOLS AND CAPABILITIES WE NEVER HAD BEFORE."

Lilly and his group didn't have to wait long. The system was up and running within days.

Reaction within the department was rapid and gratifying. "We really got excited about it," says Lilly. "Immediately, we were communicating better." And there was more – spreadsheets and word processing and a mail system. "Suddenly," Lilly said, "we had a vehicle for total open communications to every important person or department in the corporation."

Part of the story behind AMF's almost instantaneous rapport with the VAX system is that it's so easy to use. Menus and operating commands are the same for each fully integrated application. Whole functions are completed in as few as two keystrokes. And because everything is in plain English, it's literally as simple as A-B-C to incorporate



any VMS™ application into the daily work routine.

"INSTEAD OF SIX WEEKS TO DEVELOP AN APPLICATION, IT TAKES TWO."

VMS software development tools have so improved the way things are done in his department, Lilly says, that he projects the savings in applications development time and costs alone at some 70 percent.

"Many of our new applications here at AMF will be written on that machine. I can't quantify it exactly. All I know is that I'm getting a heck of a lot more bang for my buck."

The first tests of VAX equipment proved so successful, that AMF quickly enlarged the system, adding terminals and DECmate™ and Rainbow™ personal computers. New departments went on line, for example finance.

"And that," says Lilly, "really created an explosion." Now AMF is implementing programs like general ledger systems, stock options and inventory systems, and keeping more efficient and flexible records, from accounts payable to personnel.

Adds Lilly, "People here are screaming to be on the VAX system, and there's got to be a reason for that. And I tend to think that it's return on investment, mailing lists, discounted cash flows, spreadsheets they couldn't even begin to do before, versatility, tremendous graphics potential. It's just a whole world of opportunity that is elevating AMF to the forefront."

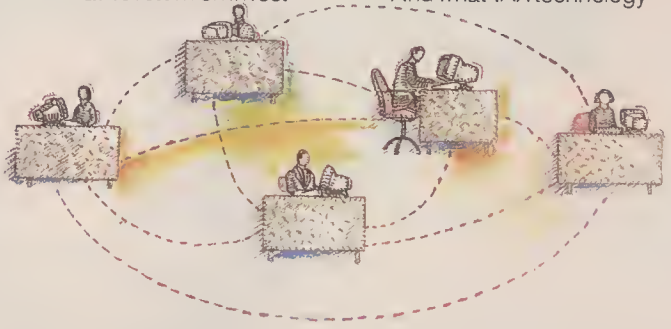
"ANYONE WHO USES VAX IS GOING TO GET THE COMPETITIVE EDGE."

Lilly feels the VAX system has already elevated his own department to the forefront.

"It's put corporate MIS on the map," he says. "It has effectively increased productivity and efficiency. People are beginning to believe we can do the things we say we are going to do."

And what VAX technology is doing for his group, Lilly believes, it can do for all of AMF, or indeed for any company. "Any corporation that employs this technology," he says, "is going to get the competitive edge.

"This technology will explode. Because there are a thousand reasons to have it. But what it really all boils down to is this: everybody will want a VAX system because they can do the job better, faster and more efficiently.



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SUPERSONIC JUMP JETS

by Paul Kinnucan

In the late 1960s, when McDonnell Douglas and British Aerospace jointly introduced the Harrier, it became the first operational combat aircraft able to take off and land vertically. Many observers considered it the start of a whole new breed of aircraft. The breed has propagated far less swiftly than anticipated, but it has begun to establish itself. The growing vulnerability of airfields and carriers may lead to widespread use of such aircraft in coming decades.

The advantages of vertical operation for combat aircraft have long been appreciated. It enables fighters to be based near the battlefront, in contrast to conventional fighters, which must operate from main bases or carriers far from the action. The ability to have aircraft on call from forward bases reduces mission time and reaction time. "You get over the enemy more often," says Randall Lowry, deputy chief of technology assessment at the Flight Dynamics Laboratory at Wright-Patterson Air Force Base in Ohio.

A vertical takeoff and landing (VTOL) capability, says Lowry, allows several fighters to take off and land simultaneously—"They don't all have to line up in a row"—and it gives a pilot excellent control because of the low touch-down speed, which would be especially beneficial in adverse weather. "You don't care about icy runways," he says. A vertical capability also allows aircraft to use damaged flight decks or runways and to be dispersed to small ships or remote landing strips. In addition, it cuts operating and maintenance costs by reducing wear and tear on wheels, brakes, and tires, and by allowing aircraft carriers to dispense with arresting hooks, catapults, and the crews required to operate them.

Vertical operation also saves on fuel by allowing what McDonnell Douglas has dubbed "ground loiter." Unlike conventional aircraft, which typically must fly to the battlefront and then loiter in anticipation of action, VTOL fighters can simply wait on the ground. Similarly, VTOL requires less fuel for landing. Bedford Lampkin, power lift technology coordinator at NASA's Ames Research Center (Moffett Field, Cal.), points out that a conventional fighter requires a fuel reserve of at least 800 pounds to make a landing. But "in the Falklands," he says, "Harrier pilots would land comfortably with 200 pounds of fuel remaining."

Because of these advantages, "jump jets" have become popular with a number of air forces, especially in Europe. The British and the Spanish navies operate fleets of Harriers, which have allowed them to dispense with expensive large carriers, and the Soviet Navy has adopted Forger jump jets for similar reasons. The British Royal Air Force uses Harriers because they can supply ground support quickly for troops and hide from attackers in dispersed locations. In the U.S., the Marine Corps has favored jump jets because their basing flexibility enables them to be operated directly under the field commander's control.

As airfields and carriers become more vulnerable, fighters that can take off and land vertically are beginning to look more attractive

Endowing an aircraft with a vertical takeoff and landing capability poses difficult design problems. To be competitive in range and payload with a conventional fighter, a VTOL fighter must have an engine capable of generating enough thrust to lift twice its empty weight—or more than twice as much thrust as a conventional fighter—requiring an engine that is also twice as heavy. This excess thrust is not used for most of the flight. For example, it is not needed for low-speed cruising, because the wings generate little drag. Neither is it needed for landing, because the aircraft will have consumed its fuel and expended its munitions in carrying out its mission. Thus, the aircraft pays a severe penalty for its vertical takeoff capability.

In addition, a VTOL propulsion system must be capable of supplying both downward thrust for lift and aft thrust for propulsion in flight. Numerous schemes have been developed over the last three decades. A scheme employed in many designs is to have the aircraft take off in a vertical attitude like a rocket ship. Once airborne, the plane tilts over and flies horizontally like a conventional aircraft.

Other schemes allow the aircraft to take off in a horizontal attitude. Some use separate engines: one for vertical thrust in takeoff and landing, and another for propulsion. After takeoff the lift engines are shut down, and the main (cruise) engine supplies propulsive power. In other horizontal attitude schemes, the same engine is used to supply both vertical and horizontal thrust; either the engine is rotated or the thrust direction is switched through a system of ducts. The Harrier uses ducts terminating in rotating nozzles that vector (direct) the thrust downward or aft as needed.

Another problem is hover control. A

A V/STOL capability would enable fighters not only to survive an attack on a main airfield through dispersal but also to resume operations before the airfield had been repaired.

Setting the stage for vertical capability

To a great extent, the design requirements for endowing fighters with a vertical takeoff and landing (VTOL) capability overlap with those for supersonic cruising and high maneuverability—properties for which there has been an increasing demand over the past decade. As a result, say many observers, the cost/performance gap between jump jets and conventional fighters is narrowing.

The large amounts of thrust necessary for vertical takeoff and landing can be put to good use in other phases of flight. In maneuvering, for example, wings generate a great deal of drag. But a powerful enough engine can overcome this resistance, enabling a fighter to make high-speed turns. Such an engine also allows an aircraft to accelerate quickly and cruise efficiently at supersonic speeds, where drag is typically twice as great as at subsonic speeds.

The maneuverability and speed advantages of powerful engines have not been lost on developers and purchasers of conventional combat aircraft. Over the last twenty years, fighter engine power has increased steadily for precisely this reason. Current-generation fighters such as the McDonnell Douglas F-15 have engines capable of generating more thrust than their combat weights. Higher power has led to a dramatic increase in the price of such aircraft, which customers have been more than willing to pay.

The capability to generate vertical thrust would seem to be wasted during airborne flight, but in fact vertical thrust can assist the wings in executing turns, allowing a tighter turn radius. At low speeds, when the wings are relatively ineffective, it can increase the lift. And at high speeds, when the turn radius is limited by the structural strength of the wings, vertical thrust can bear part of the load. (Of course, the wings could be strengthened instead, but with a penalty in the weight and cost of the aircraft.) Almost all the concepts being proposed for the next generation of Western fighters incorporate thrust-vectoring nozzles—similar to those used on jump jets—to increase maneuverability as well as shorten takeoff and landing distances.

A reaction control system, which diverts thrust from the engine to control a jump jet's attitude on takeoff and landing, could have other uses as well. For one thing, it could serve as a backup in case the aerodynamic control surfaces were damaged. Moreover, in maneuvering, a combat pilot often flies the aircraft close to stall conditions, under which the aerodynamic surfaces are ineffective. A reaction control system would allow post-stall maneuvering.

Novel aerodynamic designs under study for advanced fighters could help to solve the problems of configuring a STOVL (short takeoff and vertical landing) aircraft. For example, a forward-swept wing rooted to the fuselage near the tail would leave the space at the center of a STOVL aircraft free to accommodate the hefty propulsion system.

In the past decade, the development of high-powered engines has helped to reduce the problems with using afterburners on STOVL aircraft. A more powerful engine means that less afterburning is required on takeoff and landing, resulting in a cooler exhaust and hence a more benign footprint. Propulsion system designers have also been experimenting with cool forms of thrust augmentation such as turbofans and ejectors (jet-powered pumps that force air downward through the wings to provide lift).

Another trend favorable to STOVL aircraft is the growing reliability of jet engines. Two-engine jets have generally been considered safer than single-engine jets. But multiple engines would pose a basic problem for vertical operation: The failure of one engine could result in a thrust imbalance that would send the fighter tumbling. Today there are many single-engine fighters, including the General Dynamics F-16 and the Northrop F-20. Reliability is expected to increase with the advent of digital control systems and computer-based diagnostic systems that enable a degree of engine monitoring never before possible, and hence better preventive maintenance.

VTOL aircraft requires a nonaerodynamic means of controlling its attitude in vertical operations, when its wings are inactive. In the method most widely used, called a reaction control system, small jets of compressed air govern the plane's pitch, yaw, and roll.

An even thornier set of design problems arises when a VTOL capability is combined with a supersonic capability. "For hovering," says the Air Force's Lowry, "you want big, rounded inlets so you can suck in lots of air. But when you're out at supersonic speeds, you want nice, razor-sharp inlets so you don't create a lot of drag."

Vertical flight also dictates that the engine be concentrated as close as possible to the plane's center of gravity to minimize the size of the exhaust ducts. But this location has major drawbacks in a supersonic aircraft. For one, it tends to give the plane a "fat belly." To reduce drag at supersonic speeds, says Lowry, the fuselage should have a "Coke bottle" shape, with a narrow waist where the wings are attached.

One way to keep the fuselage slim is to reduce the size of the propulsion system. Traditionally, fighter engine designers have done this by incorporating afterburners, devices that double the amount of thrust available for maneuvering, high-speed flight, and takeoff and landing by burning additional fuel in the tailpipe. Thus the engine can be sized primarily for cruising, instead of for meeting the power needs for all phases of flight.

But because it produces a very hot, high-speed stream of gases, afterburning presents problems for a VTOL aircraft. On takeoff or landing, the hot gases could harm ground personnel or runway surfaces. In addition, the ground reflects the thrust upwards in a cloud of hot gases that can be sucked in by the engine, leading to a loss of power at a critical moment.

The VTOL fighter's requirement for a large engine, a complex plumbing system, and a reaction control system exact a severe cost penalty. As a result, most practical jump jets are not pure VTOLs. Instead they use an engine with a thrust-vectoring capability that enables them to take off horizontally over short distances, as well as vertically. In horizontal takeoffs, they rely on the wings for part of the lift, allowing the use of a smaller and hence less costly engine.

These hybrid planes are of two types: V/STOL (vertical or short takeoff and landing), of which the Harrier is an example, and STOVL (short takeoff and vertical landing). A V/STOL fighter's engine is big enough to allow the aircraft to take off vertically with enough fuel to perform some useful military missions. A STOVL fighter's engine is somewhat smaller, permitting vertical operation only for landing once the plane has returned from a mission.

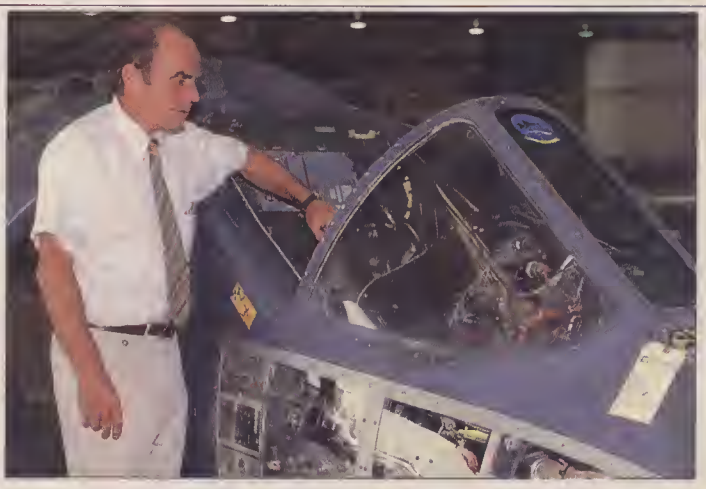
Even a STOVL configuration will still exact a penalty—either in cost (if the plane is designed to provide the same performance as a conventional fighter) or in performance (if it costs the same amount). Various studies done over the last decade suggest that the cost/performance penalty for a supersonic STOVL fighter will be about 15%, versus as much as 50% for a V/STOL fighter. Nevertheless, proponents suggest that a STOVL fighter's higher sortie rate could offset its higher acquisition

The U.S./British AV8-B Harrier (above) uses four rotating nozzles to vector 21,500 pounds of thrust generated by its turbofan engine. The Russian Yak-36MP Forger (right) employs two rotating nozzles to vector 16,500 pounds of thrust from its main engine. Two auxiliary engines mounted forward of the wings each generate 7700 pounds of additional downward thrust for takeoff and landing.

cost or lower performance, since fewer aircraft would be required to do the same job. And because they can operate from forward bases, STOVL aircraft require less range than conventional aircraft.

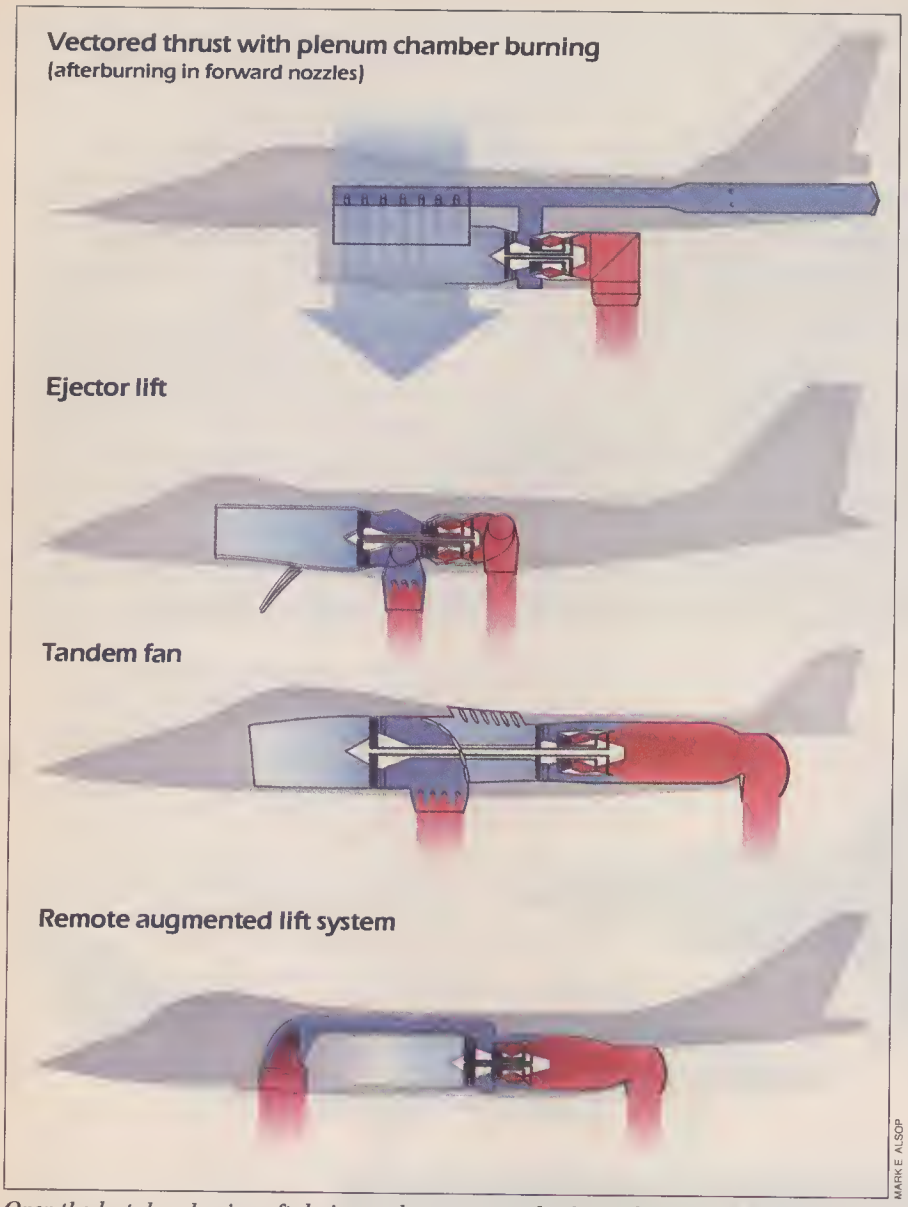
But dispersal can also pose problems of supply, control, and security. "In a war, a lot of territory changes hands quickly," says the Air Force's Lowry. "How do you tell the pilot where to go? How do you provide him with fuel and munitions? And how do you secure the site from the enemy?" NASA's Lampkin says the Navy has similar misgivings. "It doesn't think it could put an aircraft maintenance specialist on every ship," he says.

Nonetheless, the Navy has shown strong interest in dispersal in the past—and hence support for STOVL aircraft. Indeed, it had a very active STOVL fighter development program in the 1970s, prompted by plans to develop a fleet of small carriers. But when the small carrier program was abandoned, the STOVL development program withered. An official with the advanced STOVL program office in the Naval Air Systems Command (McLean, Va.), who asked not to be identified, explains that the small carrier program was scrapped mainly because it was opposed by traditionalists who favored big carriers and because the Navy concluded that developing small carriers and the necessary STOVL aircraft simultaneously would have been too expensive. Similarly, the Air Force's Lowry says that STOVL proponents "have not been able to convince the Tactical Air Command that the advantages outweigh the penalties."



NASA's Bedford Lampkin stands next to a Harrier being used to demonstrate an advanced V/STOL flight control system.

But recent events have heightened interest in STOVL aircraft. One was the



Over the last decade aircraft designers have proposed a host of different schemes for augmenting the thrust of V/STOL fighter engines. The four designs pictured here are considered the most promising for further development, but each has certain disadvantages. For example, the ejector lift concept produces the coolest footprint, but it also occupies the most space.

Falklands War, in which the Harrier proved invaluable, not only in supporting the British ground troops in the invasion—its intended role—but also in defending both the fleet and the ground troops from air attacks, a mission for which it was never intended. In addition, the Falklands brought to light an advantage of STOVL that had previously not been perceived. Royal Air Force pilots were able to operate from ships, having had no previous training in carrier-based takeoff and landing.

Another significant event was the 1982 publication of the results of an advanced STOVL conceptual design study conducted by NASA and the Navy. The study involved four aircraft manufacturers: McDonnell Douglas, General Dynamics, Rockwell International, and Vought. Each was asked to design a single-engine STOVL fighter capable of meeting the same speed and maneuvering requirements as were formulated in the early '70s for the current generation of U.S. fighters.

The resulting concepts differed widely in their aerodynamic design and propulsion systems. For example, McDonnell Douglas's 279-3 would employ an afterburning version of the vectored thrust propulsion system used on the Harrier. Because it is designed for STOVL operation instead of V/STOL, the 279-3 "can get off the ground with very little afterburning," notes Richard Martens, chief engineer of McDonnell Douglas's advanced STOVL development program. As a result, the 279-3 would be able to operate safely from carrier decks—although operation from concrete strips or the thin decks of helicopter carriers would require the use of aluminum mats.

To minimize the amount of hot gas sucked in by the engine, the 279-3 would angle its nozzles inward so that their exhaust merged into a single jet below the aircraft. Also, it would deploy a hot-gas shield from its belly during landing and takeoff.

The General Dynamics E-7 design, based on the F-16, would employ two wing-mounted ejectors—which use engine exhaust to entrain a large mass of slow-moving air downward through the wings—for thrust augmentation during landing and takeoff. Additional thrust would be supplied by a thrust-vectoring nozzle on the fuselage. General Dynamics chose this design in order to eliminate the problem of hot gas reingestion, according to the company's report to NASA.

Rockwell International's design employed four wing-mounted ejectors. Vought's futuristic TF-120 would have a propulsion system similar to that used by McDonnell Douglas. The chief difference is that its engine employs two turbofans instead of one. This "tandem fan" design would produce very high thrust, thereby requiring even less afterburning for vertical operations than does the McDonnell Douglas design.

All the resulting designs met the NASA/Navy study's performance specifications—at least on paper. Moreover, they came in at about the same weight as current fighters. Theoretically, then, they could be built at about the same cost.

The results of the study were presented at the Paris Air Show in 1983 to a gathering of high-ranking British and U.S. defense and aerospace officials that included Hans Mark, then deputy administrator of NASA, and Richard DeLauer, then head of the Pentagon R&D effort. Mark was so excited by the results that he reportedly stood up and exclaimed, "Let's build an aircraft!" DeLauer and his counterpart in the British Ministry of Defense were said to be likewise enthusiastic.

NASA has since proceeded to the next stage, testing nine-tenths-scale models of the E-7 and the 279-3 in wind tunnels. Preliminary results are "very encouraging," says Samuel Wilson, acting group leader for the supersonic STOVL program at NASA-Ames.

Meanwhile, representatives of NASA, the Defense Department, the British Ministry of Defense, the air forces of both countries, and the major aircraft makers have been meeting regularly to

These STOVL fighter concepts, developed by NASA contractors in 1980–82, incorporate advanced aerodynamic and propulsion system features that enable them to approach or surpass the performance of conventional fighters now flying. For example, the tandem-fan propulsion system and streamlined shape of the Vought TF-120 would enable it to cruise supersonically.

work out the details of a collaborative effort for advanced STOVL R&D. The idea is to avoid duplication of effort, thereby getting increased leverage out of the limited funding currently available from each government, and to put pressure on policymakers to increase the level of funding. Proponents point out that a similar joint program led to the development of the Harrier in the 1960s.

Reportedly, a final plan was reached last February in a meeting at NASA's Langley Reseach Center in Virginia. All that is required to set the program in motion is the signing of a memorandum of understanding between the two countries, which is now being finalized.

Despite these developments, not all the major services are sold on the desirability of STOVL fighters. But advocates such as NASA's Lampkin remain optimistic. Not only are airbases and ships growing increasingly vulnerable to highly accurate long-range missiles—creating a need for planes that can operate from other types of surfaces—but the military is already planning to build aircraft that incorporate many of the features of STOVL fighters.

In the generation of fighters now being planned for the 1990s, the air forces of the West want to achieve better maneuverability. This will entail more powerful engines and hence greater thrust-to-weight ratios. They also want the planes to be able to cruise at supersonic speeds for long distances. To do this efficiently will require a significant increase in the thrust of the engines without afterburning. The U.S. Air Force is already talking of adding elements of V/STOL, such as thrust-vectoring nozzles and reaction control systems, to conventional aircraft to allow shorter takeoffs and landings. With the addition of these STOL features, observes Lampkin, "you're just one step away from V." □

Paul Kinnucan is a senior editor of HIGH TECHNOLOGY.

For further information see **RESOURCES** *on page 69.*

BUSINESS OUTLOOK

Supersonic V/STOL: gearing up for the '90s

The federal government is following two routes in funding work on supersonic aircraft that can use relatively short runways. One path would lead to the possible integration of short takeoff and landing (STOL) capability in the next generation of fighter aircraft, spelling multibillion-dollar contracts for the aerospace firms that best master this technology. The other, less developed path would lead to machines that could also take off and land vertically (V/STOL).

The growing interest in V/STOL aircraft has been stimulated by several factors, according to Wolfgang Demisch, aerospace analyst at First Boston (New York). Advanced munitions can easily destroy the long runways ordinarily needed by military aircraft. What's more, the Navstar satellite-based navigation system, currently being put into operation, permits constant and extremely accurate position determination—a critical ability for a V/STOL aircraft trying to find its way to small landing patches in darkness or foul weather. Finally, the subsonic Harrier V/STOL proved to be a maintainable, flexible weapon system for the British in the Falklands campaign.

The fate of supersonic STOL aircraft that can implement more extensive air-to-air combat missions is directly tied to prospects for the Advanced Tactical Fighter (ATF), the Air Force's proposed replacement for the F-15 Eagle. To investigate the feasibility of STOL technology for ATF or any other high-performance fighter, a Short Take Off and Landing and Maneuver Technology Demonstrator (SMTD) program has been initiated by the Flight Dynamics Laboratory of the Aeronautical Systems Div. at Wright-Patterson Air Force Base (Dayton, Ohio). McDonnell Douglas (St. Louis), developer of both the F-15 and (with British Aerospace) the Harrier, was awarded the prime contract in October 1984. The major subcontractors are Pratt & Whitney (West Palm Beach, Fla.), GE's Flight Control Division (Binghamton, N.Y.), and the National Water Lift Division of Pneumo (Kalamazoo, Mich.). Of the project's $117.8 million in funding, $75 million comes from the government, and the remainder is being provided on a cost-sharing basis from direct earnings of McDonnell Douglas and Pratt & Whitney. The project is scheduled to run for five years.

Wolfgang Demisch, Aerospace Analyst, First Boston

"In future military combat aircraft, short takeoff and landing capability will be the norm, rather than the exception."

The program's initial purpose is to use an F-15 as a test-bed for evaluating the transferability of particular technologies to the ATF or future versions of current fighters. As explained by David Selegan, deputy program manager at Wright-Patterson, the aircraft will be flight-tested for about a year. "If the technology proves to be sufficiently mature for use in the ATF, there will be an annual industry review at which companies involved in the ATF will be shown what has been going right or wrong. That way, we keep an open field."

There is another possible game plan—one that could significantly boost the Western market for fighter aircraft, currently estimated by First Boston's Demisch at $12 billion a year. Supersonic STOL capability could be incorporated into a continuing series of interim upgrades, not only for the F-15 but also for some of the fighters turned out by General Dynamics, Grumman, and Northrop. This would enhance and extend the revenue potential of such planes. Demisch sees this route as "highly probable." "Since it could cost $5 billion just to get ATF off the ground," he says, "it may prove easier to modify existing products."

"The F-15 technology demonstrator program is a significant key to McDonnell's winning future high technology fighter business."

Bill Brinks, SMTD Program Manager, McDonnell Aircraft

Beyond STOL lies V/STOL. Because engineering and design challenges are much greater than for a pure STOL machine, any supersonic "son of Harrier" is farther back on the long R&D cycle. No military agency has yet established a requirement for supersonic V/STOL, but NASA has carried out in-house and contract research on V/STOL propulsion systems for several years at its Ames and Lewis Research Centers. The rationale for this work, says Jack Levine, director of flight projects at NASA headquarters (Washington, D.C.), is to "develop the knowledge base so that potential users have a reservoir of validated technology they can dip into when future flight machines are considered."

To this end, NASA has given several aerospace firms contracts, partly funded by the Naval Air Systems Command, for testing propulsion concepts that might be used in V/STOL configurations. General Dynamics (Fort Worth, Tex.) is engaged in high-speed wind tunnel testing of its E-7 model, featuring an ejector augmentation system, as is McDonnell Douglas with its vector thrust–based 279-3. De Havilland (Toronto) is also working on an ejector-type concept. In addition, NASA is close to reaching agreement with Great Britain on a joint research project to compare and evaluate the leading propulsion systems. The most cost-effective technology might then find its way into a demonstrator craft late in the next decade.

Why are the airframe companies interested in a program with such remote payoffs? The reason, says Don Whittley, program manager for advanced R&D at de Havilland, is that "you have to maintain your technology base."

—Dennis Livingston

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HEALTHCARE LOOKS BEYOND THE HOSPITAL

by H. Garrett DeYoung

Remember the one about the patient who feels fine when he checks out of the hospital, then has a heart attack when he sees the bill?

Today it's the nation that's reeling, and for the same reason: The cost of medical care in the U.S., now close to $400 billion a year, is threatening to go out of control.

An acute cost-awareness has thus arisen in virtually every sector of the medical industry. Limitations are being put on Medicare payments, and some private insurers are following suit. Moreover, rules prohibiting reimbursements for many tests and treatments outside hospitals have been changed.

One of the most important outcomes is a strong movement toward alternate-site medicine: the delivery of health services outside the costly hospital setting. Using a combination of new technology and innovative marketing, dozens of companies, both new and old, are bringing medical diagnostics and treatment into almost every corner of American society.

Diagnoses that were once run in the hospital or in clinical laboratories are now being performed in doctors' offices in minutes—and at a fraction of the cost charged by the big automated labs—with inexpensive desktop analyzers; other types of technology alert physicians to such problems as heart disease or premature birth. More than 100 surgical procedures are now performed routinely in hospital outpatient units and private "surgicenters." And a growing number of treatments (kidney dialysis and continuous antibiotic therapy, for instance) are being administered in the home.

Despite the burgeoning interest in these and other alternate-site technologies, many of the products and services are still limited to a relatively small number of patients, at least until physicians are convinced of their safety and efficacy. But while market analysts note that alternate-site technology is still embryonic, they believe that it could grow into a business worth billions of dollars a year. "We don't expect it to peak until at least the end of the decade," says Saundra Woodruff, an analyst with market research company Biomedical Business (Tustin, Cal.).

Diagnostics: think small. Much of the new technology focuses on small chemical analyzers—tabletop instruments with which private physicians can test patient fluids for infection and other common disorders cheaply and within minutes.

The marketplace battle for such instruments has recently been joined by some of the nation's top healthcare-related companies, including Kodak, Mallinckrodt, Boehringer-Mannheim, Abbott, American Hospital Supply, and Becton-Dickinson. Several others (DuPont and Baxter Travenol, for example), already major suppliers of clinical instrumentation to hospitals and large laboratories, have not yet entered the ring but are said to be seriously considering such a move. This year's sales of diagnostic equipment to the 40,000 or so physician-owned laboratories are estimated at $300 million, according to Business Communications, a market research company based in Stamford, Conn. The number of such laboratories is expected to reach 70,000 by 1990, and the selection of diagnostic tests is growing. As a result, says Business Communications, revenues should more than double, reaching $650 million a year.

Many of the analyzers are based on the principles of immunochemistry, a science dealing with reactions between antigens (foreign chemicals or organisms) and chemicals called antibodies. Hospital analyzers run scores of different tests and cost $100,000 or more; thus they require considerable amounts of capital and technical skill. But the small office units generally run the most common, easiest-to-interpret analyses, and are priced so low (in some cases less than $1000) that even the cost-conscious solo practitioner is considered an important part of the market.

One example is Kodak's Ektachem DT60 analyzer. The unit, about the size of an office typewriter and priced at about $6000, is being promoted to both solo and group physicians in general practice, as well as to cardiologists, pediatricians, and other specialists. By 1990 the market is expected to comprise about 140,000 offices, according to Kodak's marketing director, Dan D. Shilt.

The DT60 performs seven different blood tests (including glucose, urea nitrogen, and cholesterol) that the company says account for more than 80% of the physician's needs. Up to 18 more tests—ammonia and hemoglobin, for example—

ILLUSTRATION BY IVAN POWELL

will be added in the near future. Shilt notes that despite its small size, the analyzer (which can run up to 70 tests per hour) is based on the same "dry chemistry" principles as Kodak's hospital units; that is, no plumbing or wet reagents are required.

The instrument is used as follows: A drop of patient blood serum (the portion of the blood remaining after the red cells and other components are separated) is placed on a plastic slide about the size of a postage stamp, which is then inserted into the analyzer. An internal detector reads a bar code on the slide that identifies the test being run. The slide then moves automatically into an incubator, where the serum component that is being analyzed (the analyte) reacts with a chemical on the slide to produce a color change proportional to the analyte concentration. The slide is then automatically transferred to a station where it is illuminated by a fiber optic device; the reflected energy is transmitted to a "read" station for analysis by a microprocessor. Finally, the analyte concentration is printed on a small tape by a built-in thermal printer.

Another automated analyzer for the physician's office is the Reflotron, a new enzyme-based device produced by Boehringer-Mannheim Diagnostics (Indianapolis), a company with more than 20 years' experience in medical instrumentation, diagnostics, and biomedical products. Like the Kodak unit, the Reflotron (also priced at about $6000) will run up to 24 different blood tests, each taking one to three minutes. Unlike the DT60, however, it uses whole blood—usually just a few drops from a finger-prick—thus saving the serum separation step.

Instead of film, the Reflotron uses an array of small paper strips, each consisting of several thin layers. Encoded on the back of each strip are up to 500 bits of information that instruct the microprocessor on incubation time, temperature, reactants, and other test variables. A drop of blood is touched onto the strip, which is then inserted into the machine. As the blood passes through the layers, various components are separated out through a series of chemical and physical reactions, so that the final layer contains only the blood

Kodak's DT60 analyzer uses a pretreated dry film to automatically perform several common blood tests in the physician's office. Until recently, such tests were usually run in hospitals or large clinical laboratories.

serum and the analyte.

At this point, the analyte reacts with an enzyme (a protein, preimpregnated into the strip, that binds specifically to one or a very few other types of molecule, such as glucose). The reactants are then analyzed by a built-in optical device called a reflectance photometer, and the value is printed out.

A more expensive instrument was recently introduced by Abbott (North Chicago). Called Vision, the $18,000 analyzer uses a few drops of whole blood to perform up to 10 analyses, alike or different, in about 10 minutes. Using the company's premeasured individual test packs, Vision now runs eight tests, with four more scheduled to be introduced by year's end. Like Kodak's DT60, the instrument is said to cover some 80% of the analytic needs of most private physicians.

The marketplace is not yet full, says product manager Byron Hewitt: "We'll see a few more companies getting into this kind of instrumentation, then we'll all slug it out."

The appeal of such instruments goes far beyond cutting the nation's medical bill; they are also proving to be important profit centers for the vendors' physician customers, especially if they belong to one of the nation's more than 16,000 group practices (in which profits are typically higher and funds for new instrumentation more available). A recent survey by the Market Technology Group (Stamford, Conn.) indicates that approximately 85% of the group practices perform in-office diagnostics and that the average cost of such a test is less than $2.

Listening with micros. Low-cost microcomputers and diagnostic algorithms are being put to work in other medical areas, often resulting in dramatic savings of both time and money. An example is the small computerized cardiac monitor developed by Circadian (Sunnyvale, Cal.). The instrument is based on a 20-year-old device called the Holter monitor, which is worn by a heart patient during a normal day. During this time, the heart's electrical function is recorded with the aid of electrodes attached to the chest; the cardiologist then removes the instrument and scans the recording for abnormalities. Interpretation is often a lengthy process and usually requires a trained analyst.

Priced at less than $20,000, Circadian's device, called the CircaMed, costs only about a third as much as the Holter monitor, according to president Robert Sudol; it is also much smaller, and it records continuously for up to 48 hours. The built-in computer then prints out the recorded data in an easy-to-interpret format while the patient waits in the office. Circadian hopes to sell or lease the CircaMed to as many as 100,000 physicians. Sudol claims that a customer who leases can break even on one or two procedures a month over a 10-month period. "Our marketing program is based on the idea that analyses done in the doctor's office are faster, more convenient, and much less expensive," he says.

The company has also developed two other small instruments aimed at the private physician: a programmable three-channel electrocardiograph and an automated instrument for assessing the efficiency of the respiratory system.

The ambulatory uterine activity monitor is another instrument for tracking possibly abnormal conditions. Marketed by Tokos Medical (Irvine, Cal.), the monitor—which is prescribed by the patient's physician and leased from Tokos—alerts expectant mothers to premature labor by measuring uterine pressure through a small sensor attached to the abdomen. Until recently, the only way to predict premature labor before it actually began was through regular cervical examinations by a physician.

Up to 10% of expectant mothers are at risk for premature labor, says David Mildrew, Tokos's vice-president of administration. To use the monitor, the mother simply attaches the sensor twice a day and goes about her normal routine. The device is then removed by a Tokos nurse, and the recorded data are transmitted by phone to a central station for analysis.

Several other companies offer computer programs and databases for assisting physicians in their diagnoses and streamlining patient record keeping. An example is the series of programs from Cogitum Medical Software (Ann Arbor, Mich.), a year-old company that is targeting private offices, as well as clinics and hospitals. The software is priced from $450 to $1300 and runs on IBM or Apple II personal computers. Cogitum now sells three types of programs, according to marketing director Maureen Penfold: history-taking, patient management (for tracking medication and laboratory results), and report-writing.

Cogitum's history-taking programs include extensive databases for such

WM. FRANKLIN McMAHON

Cost-awareness has created a new healthcare market, says American Hospital Supply's Moffitt. The company has recently developed several desktop analyzers, such as these automated blood cell counters, to complement its line of hospital-based instrumentation.

problems as chronic headache, back pain, and behavioral disorders. As the patient or the physician sits at the computer, an interactive routine leads him through a series of questions and symptoms; an answer (usually typed as either "yes" or "no") may carry the dialogue into another level of complexity as the program probes for increasingly specific information.

Penfold stresses that the programs are not diagnostic tools in the strict sense, since such terms carry certain legal connotations; rather, she refers to them as labor-saving devices that can often shorten the diagnosis process by eliminating some possibilities and highlighting others (depending on how the answers fit into the database). And while some critics claim that such programs depersonalize the physician–patient relationship, Penfold and others maintain that the opposite is true: The time saved in gathering routine data can be spent in more meaningful dialogue.

Home sweet home. Diagnosis is only a part of the total healthcare picture, of course. Medical costs are also being reduced by treatments that can be performed by many patients at home. The market—which includes not only the drugs used in the treatment but also auxiliary equipment, such as small programmable pumps—now consists primarily of special nutritional products and services (aimed at patients with abnormal digestive systems), kidney dialysis, and continuous intravenous drug administration. Within a few years, home therapies will almost certainly embrace such intractable disorders as Alzheimer's disease and many forms of physical rehabilitation.

The benefits of such procedures, moreover, extend well beyond lower costs. Recovery or remission rates for many patients are dramatically enhanced in the familiar and comfortable home environment.

As with office diagnostics, home healthcare is not lacking for corporate players. Recent entries include Baxter Travenol, Abbott, Home Health Care of America, Mead Johnson, and Chesebrough-Ponds. Most or all furnish not only the required products, but also home delivery, patient education programs, and private nursing services.

In the form of home nutrition care called total parenteral nutrition (*parenteral* means "ouside the digestive system"), the patient periodically attaches a prepackaged nutrient solution to a permanent catheter that feeds into the circulatory system through one of the body's major vessels. Although the technique completely bypasses the digestive system, it provides all the nutrients required by the body. Enteral nutrition is a simpler, oral form of therapy that is often prescribed for patients who have some degree of digestive function.

The annual domestic market for enteral and parenteral nutrition alone (including the delivery systems) is approximately $1.2 billion, according to Janet Lindholm, a spokesperson for Mead Johnson (Evansville, Ind.), a major enteral products supplier. Hospitals still account for the largest share, but sales to the home-use segment—estimated at about $100 million in 1984—are expected to double by 1990 as alternate-site healthcare continues to grow.

Another example of advances in home healthcare is the continuous ambulatory peritoneal dialysis (CAPD) system marketed by several companies, including Travenol Laboratories (Deerfield, Ill.), a division of Baxter Travenol. The company's CAPD system is now used by about 25,000 kidney patients worldwide; formerly, these patients required hemodialysis, an expensive process in which the blood is cleansed of impurities—a task normally handled by the kidneys—by routing it through a large filtering device several times a week. Besides requiring access to a dialysis machine, the process takes three or four hours, during which time the patient is almost completely immobilized. The CAPD not only allows the patient to live a near-normal life, says Steven Lazarus, Travenol senior vice-president, but also represents per-patient savings of about $6000 a year.

For a patient to use the CAPD system, the physician first installs a catheter extending into the patient's peritoneal cavity (a large space in the abdomen that is bound by a thin piece of tissue called the peritoneal membrane). Three or four times a day, the patient attaches the tube to a plastic bag containing a premeasured, premixed dialysis solution. The liquid flows by gravity into

E.C. WISNER

Circadian's portable cardiac monitor, the CircaMed, uses a built-in computer to analyze electrical data from the heart. The device is much less costly than older instruments, says company president Sudol, and the results are easier for the physician to interpret.

A kidney patient in Japan uses peritoneal dialysis, in which a solution that is fed into the abdomen removes wastes from the blood. Thousands of patients worldwide can substitute this procedure for costly and inconvenient hemodialysis.

the peritoneal cavity. As the blood flows through the membrane, the wastes normally removed by the kidneys flow out of the membrane's capillaries by osmosis into the dialysis solution; vital nutrients and minerals in the solution flow out of the cavity into the bloodstream. After a few hours, the patient removes and discards the plastic bag and replaces it with a fresh one.

Travenol also markets a home chemotherapy system for cancer patients, many of whom would normally have to receive anticancer drugs in a hospital or in the physician's office. Patients who are healthy enough to live at home, however, can often use a continuously administered, prepackaged drug or combination of drugs. In the Travenol system, the drugs are contained in a small plastic pouch that is attached to a catheter. A portable programmable pump delivers the drugs into the bloodstream at a slow, constant rate. One of the system's advantages, says Lazarus, is that the steady infusion of such drugs often eliminates the side effects, such as nausea, that usually accompany large doses.

A similar method for self-administration of drugs is the intravenous antibiotic package developed by Abbott. The package, again consisting of premixed drugs in disposable containers, is targeted to "patients who don't require hospitalization but do need a fairly constant intravenous antibiotic treatment for certain types of infection," says Robert L. Parkinson, general manager of Abbott's home care unit. Most ambulatory patients quickly learn how to administer the drugs at home by way of a catheter.

Obviously, not all patients are suited to home healthcare. Besides having to be healthy enough to spend most of their time outside the hospital, home-care patients must be able to understand how the therapy is used and why it is needed. A supportive home setting is also desirable.

Selling to the home-use market (either directly or through traditional medical distribution channels) is much different from selling to physicians and hospitals, says Travenol's Lazarus: "It's very important that the device be easy for the patient to understand and use. And it can't look intimidating."

In-and-out surgery. Until recently, surgery almost always meant hospitalization (which in turn required a battery of admission tests and at least one night in the hospital). New, low-cost instrumentation and the trend toward less invasive methods are cutting the cost of many elective procedures by more than 50% by moving them into physician's offices and hospital outpatient centers.

Travenol's Lazarus displays a programmable syringe that administers anticancer drugs continuously, allowing many patients to receive chemotherapy at home. Continuous infusion often reduces the unpleasant side effects of single large doses.

Another important development has been the rise of privately owned ambulatory surgical centers (sometimes called "Docs in the box" by critics who liken them to fast-food outlets). The number of such centers, which are not associated with hospitals, has grown from about 400 in 1982 to 1200 today, and is expected to reach about 4500 by 1990.

"The hospital operating room is a very expensive place to be," says William S. Hotchkiss, vice-chairman of the board of trustees of the American Medical Association in Chesapeake, Va., "so we encourage procedures that can be done effectively in other settings."

Some 120 operations have been assigned to outpatient management by the Department of Health and Human Services, including some forms of cataract surgery, hemorrhoidectomies, hernia repair, and relatively minor orthopedic and gynecological operations. One reason many of them are now performed in nonhospital settings is the availability of disposable surgical packs, which contain sterile gowns, drapes, dressings, and in some cases the required instruments. Alternate-site medicine has made surgical packs a $400 million market, says a spokesperson for American Pharmaseal (Glendale, Cal.), a major supplier.

Other operations are benefiting from new instrumentation. Some orthopedic procedures that once required several days in a hospital bed and weeks of painful rehabilitation are increasingly being performed in a doctor's office in an hour or so. A major reason for these savings is the development of new arthroscopic devices, such as the disposable fiber optic tool developed by American Hospital Supply. The instrument is threaded into the body (most often into the ligaments or cartilage surrounding an injured knee or elbow) through a small incision. With the injury site in view through the optical fiber, the surgeon switches on an electric current and cuts through the tissue with tiny sparks emitted by a lead in the center of the fiber. Whereas such repairs once required the opening of the entire joint, this much less invasive surgery often allows the patient to be up and about in a day or two, with only a Band-Aid over the incision.

Clinical trials have recently been launched at six U.S. medical sites in preparation for FDA approval. The device should be commercially available (for less than $100) by early 1986.

Certain types of eye surgery have also been assigned to outpatient status by the government. An example is the repair of secondary cataracts, clouding of the lens membrane that sometimes occurs after a cataract operation. Until recently, these disorders required a second expensive operation in the hospital—a traumatic experience, especially for the elderly. "These patients often think that their cataracts are coming back," says an American Hospital Supply spokesperson. "Many of them just decide to live with the condition rather than go through the discomfort of another operation." But now, secondary cataracts can usually be repaired in a doctor's office with a laser such as the YAG-100, an yttrium-aluminum-garnet laser marketed by American Hospital Supply. The procedure is painless and takes less than an hour.

A related operation is performed with the aid of the Cryolathe, produced by Steinway Instruments (San Diego), a 20-year-old company that specializes in human vision technology. The $75,000 computer-aided device allows physicians to permanently correct near- and farsightedness in certain cases. The Cryolathe is now being used in about 15 U.S. outpatient units, according to Steinway vice-president Eric Weinberg.

Through conventional diagnostic techniques, the physician first determines the refractive properties of the cornea (the tissue on the surface of the eye) and enters the data into a personal computer; the program calculates the type and extent of surgery that will be required to normalize the cornea's shape. In a simple and painless opera-

tion, the physician removes a portion of the cornea, freezes it, and mounts it on the Cryolathe, which reshapes it in much the same way that a contact lens is shaped on an optician's lathe. Finally, the cornea is thawed and reattached to the eye. The entire procedure, says Weinberg, takes only about half an hour.

Despite its seemingly wide appeal, the operation is presently recommended mostly for severe vision problems. Until longer-range data are gathered (on possible complications of the procedure or the effects of scar tissue after 10 years, for example), patients are still generally advised to keep their glasses and contact lenses on.

Plugging in. It's probably too early to predict how alternate-site medicine will affect the healthcare system of the nation's economy as a whole. One reason for the uncertainty is that the commercial success of the new technologies depends heavily on their acceptance by physicians—traditionally a very cautious consumer segment. "Doctors aren't usually willing to change the way they do things," says Circadian's Sudol. "Even though they may like the technology, there's a bit of suspicion about something new—especially if it's much simpler than what they've become accustomed to."

Another reason for the uncertainty is that the healthcare marketplace "is clinically driven, not technology-driven," says Ruth Emyanitoff, a consultant with Boston Biomedical Consultants (Waltham, Mass.). "A physician performs an operation because the patient needs it, not merely because the technology is there." But as new techniques and instruments become available, she adds, they will probably see wider use.

Few companies have been put off by these uncertainties, however, especially among those that have already established a track record in healthcare. American Hospital Supply (which recently announced that it intends to merge with Baxter Travenol) is just one example of how large, older companies are plugging into alternate-site concepts. Once a major distributor of medical products ("everything from Band-Aids to heart valves," says vice-president and general manager William P. Moffitt), the company has evolved over the past few years into a major producer of healthcare equipment and services, including large automated diagnostic instruments for hospitals and clinical laboratories. The company scored $3.4 billion in sales last year, maintains a $100 million annual R&D budget, and now manufactures nearly half its products. American's 1984 sales to nonhospital healthcare sites amounted to $200 million, a 23% increase over 1983.

JOSEPH STERLING

Secondary cataracts, which once required hospital care, are corrected quickly and painlessly in the doctor's office with a brief pulse from a laser such as American Hospital Supply's YAG-100.

Other companies are also enjoying the fruits of the changing medical scene. While Abbott (with total 1984 sales of $3.1 billion) declines to reveal its alternate-site sales figures, the company is placing special emphasis on two areas: the design of new office diagnostics and the development of additional home care systems, in collaboration with hospitals. And at Travenol, Lazarus says that domestic nonhospital sales added up to about $300 million last year, or about 15% of total revenues.

MDs are cautious. Predictably, not everyone embraces these developments. While physicians strongly encourage patients to become more involved in their own healthcare, some of them worry about the growing number of "storefront" ambulatory care centers that AMA's Hotchkiss terms "more innovative in their management than in their medicine." (The AMA also takes a generally dim view of the growing number of private emergency-care centers, asserting that true emergency care implies 24-hour-a-day service. Few of the freestanding "emergicenters" offer such service, says Hotchkiss.)

Nevertheless, most MDs recommend certain home diagnostic kits that enable patients to detect disease in its early stages and to monitor treatment programs. In many cases, these kits are valuable adjuncts to traditional medical treatment; one example is the home tests by which diabetics—who are carefully instructed in the interpretation of the results—can track blood sugar levels. But self-examinations for life-threatening disorders such as cancer is often decried by physicians on the grounds that such diagnoses are too important to be left to the judgment of the layman. And even simple and generally accurate home tests may be compromised by the patient because of the need to perform certain distasteful tasks (such as drawing blood or collecting stool samples).

Despite such reservations, it seems clear that alternate-site healthcare is much more than a passing fad. For the executive who can look beyond today's healthcare landscape, the message is clear, says Abbott's chairman, Robert A. Schoellhorn: "[Commercial] success will be directly proportional to a company's ability to offer products and services that reduce overall healthcare costs and that make the healthcare system itself more productive." And for doctors and patients, the benefits will extend well beyond a more manageable national medical bill; they will include a streamlined healthcare system—one that is more responsive, less invasive, and far less traumatic—with a better utilization of hospitals and other major medical resources. □

H. Garrett DeYoung is a senior editor of HIGH TECHNOLOGY.

For further information see **RESOURCES** *on page 69.*


PAIR?
PARE?
PEAR?

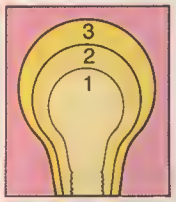
Would you like to know how computers can tell the difference between a pair in a poker game and a pear on a plate?

How they can understand a variety of speakers with a diverse variety of accents—and reply in pear-shaped tones, using normally connected speech?

Then read on to learn more about computers that recognize words, comprehend meaning from context, even synthesize human speech from a mere shadow of itself.

It's All In The Algorithms

Utilizing three levels of speech-processing algorithms, AT&T is giving the computer a more 'robust' understanding—the capacity to comprehend connected speech from different speakers.



Three levels to understanding

Acoustic pattern matching (1) identifies the spoken words.

Grammatical processing (2) figures out how the words are put together.

And semantic processing (3) extracts meaning from the context. With each successive step, the computer moves closer to accurate understanding.

Acoustic pattern matching determines how much latitude the waveform (pronunciation) of a word can have before it becomes unintelligible to the computer.

By isolating the specific characteristics the waveform of a word contains—independent of the accent of a speaker—we increase the probability that it will be correctly matched to a pattern stored in a computer's memory. But, correct recognition of words is only the beginning of computer understanding.

Computer Grammar 101

Grammatical processing further increases the probability of recognizing words. It analyzes them within the constraints imposed by language—the allowable sequences of syllables in a word or words in a sentence.

For a specific vocabulary and situation, it is possible to define every sequence the computer can recognize. Based on probabilities assigned to each word it recognizes—and where that word falls—the computer determines which of its possible sequences is the most likely. This process gains two advantages: It allows words that might not otherwise be recognized to be correctly accepted; and it speeds up processing time by using sequence position to limit the number of words it looks at for a pattern match.

A Meaningful Relationship

Semantic processing is the point where the computer crosses the line between recognition and understanding—the point where words are given meaning within a specific context. This endows a system with one of its most human qualities: knowing when a request isn't understood, and asking for appropriate clarification.

Talk Isn't Cheap

Making a computer listen intelligently is one thing; making it respond intelligibly, however, is another.

Enabling a computer to talk, reproducing the subtleties of human speech, has required large amounts of memory—a high cost item. Therefore, an 85 percent reduction in the amount of information needed to store and generate high-quality speech can mean significant cost reductions.

That's just what a new AT&T speech synthesis technique, called multi-pulse linear predictive coding (MP-LPC), provides. It reduces the 64 thousand bits per second previously needed to 96 hundred.

Speech signals mimic the human vocal tract—they have redundancies built in. MP-LPC codes speech to remove these redundancies, then tells the computer how to reconstitute the original speech from the mini-version in its memory. This coding eliminates unnecessary bits from being stored and transmitted.

Getting Down To Business

At AT&T, our goal is to make computers listen and understand as fast as people speak—and speak to and understand as many people as possible. Speech-processing algorithms, developed by AT&T Bell Laboratories, have moved us several steps closer to that ideal.

For example, most speech recognition systems make the speaker pause between words. But AT&T, using advanced recognition algorithms, has developed a Stock Quotation System, now in field trial, that allows callers to enter and retrieve current market information in natural, normally-connected speech. Users simply speak the number codes for any of over 6,000 stocks, and the service provides current quotes—delivered in computer-generated speech.

Numbers are nice, but make for limited conversation. Closer to our goal of a conversational computer is the Flight Information System. It uses the Official Airline Guide as its data base. In its limited environment, this laboratory system converses with the user in natural speech in response to normal flight information queries.

One Of Our First Callings

AT&T has been deeply involved in speech technology since the genesis of the telephone. From the beginning, our goal was to make mechanical communications fast, foolproof and economical.

Today, with the advent of the computer, we're moving toward the ultimate ideal: creating machines that serve our needs and save our energy in the most natural manner—by voice command.

AT&T

The right choice.

FILE-TRANSFER HEADACHES—AND CURES

New hardware and software can help communication between micros

Sometimes computers seem to create as much work as they save. Getting a file from one computer to another is often such an ordeal that many people simply retype the information, violating one of the basic tenets of computer philosophy.

The lack of compatibility among computer products, in both hardware and software, has been a persistent problem, yet some standards are emerging. Among other things, they should ease the most common file conversion problem: moving text between machines.

Moving a file generally breaks down into two often intertwined steps: media conversion and format conversion. Media conversion is usually a physical step, turning the information into a form that the receiving computer can read. It can be performed through disks, telecommunications, or optical scanning of printed copies. Format conversion makes the document layout and structure intelligible to the receiving computer and software.

The fastest and cheapest means of media conversion is through disk-reading software, programs that can read the source disks directly on the receiving computer by temporarily changing the disk format.

Bidirectional media conversion between the IBM PC and most CP/M-80 micros with 5¼-inch disks is fairly easy through software (HIGH TECHNOLOGY, April 1984, p. 30). Four effective choices (the format count depends on disk drive hardware) are UniForm (over 70 formats, $70), Convert (108 formats, $99), Award (30 formats, $99), and Xeno-Copy (105 formats, $150).

A second solution is to connect the two computers via their serial ports or through the telephone line with a pair of modems. Telecommunications software makes the process easier. Such programs should be capable of sending and receiving binary files in addition to simple text. A few dedicated word processors have no communications ability at all, so conversion is practical only via disks; others will transmit only unformatted text. Wang systems will send complete files, but only in a synchronous form, requiring a hardware protocol converter for connection to a standard micro; the M/H Group makes such a converter ($1200), which includes file format conversion between Wang office products and MultiMate, OfficeWriter, and DisplayWrite 3 word processors on the IBM PC.

The fastest and cheapest means of media conversion is through disk-reading software.

Between the IBM PC and the Macintosh, the excellent MacLink package ($125) can perform bidirectional transfers with format conversion between MacWrite and WordStar or MultiMate in MS-DOS. MacLink runs on both machines; once the program is loaded onto the IBM PC, you can control everything from the Macintosh, including changing subdirectories and disk drives on the IBM PC. The format conversion is limited but useful. It cannot deal directly with font and type sizes, since WordStar and MultiMate do not have such features; instead the program changes the point sizes to different character densities, from 5 characters per inch to 13.2 characters per inch in MultiMate, or to normal and alternate pitch in WordStar.

If you get stuck, several tricks can help out. If you don't have a communications program for the sending machine, you can have it print the file and intercept the data going to the printer with a receiving computer. If the sending computer uses a parallel printer, you must connect a parallel-to-serial converter. If you need to move only the text that appears on the screen, you can use the print screen command or a utility program available on many computers.

Once you have managed to move a text file, what can you do with it? All programs that create a text document store two kinds of information: the text itself and the formatting—the left and right margins, page breaks, tabs, and so on—which is generally interleaved with the text. There are hundreds of formatting schemes in use. Text files come in four forms: raw, page-image (final form), text-only, and revisable.

The raw document is the native file created by a word processor, complete with formatting information. While some raw documents can be made intelligible with only light changes, others are essentially unreadable by a second program. The standard characters are usually stored in 7-bit ASCII, a nearly universal coding, but word processors with an extended character set (foreign language accents and symbols) use their own unique coding. Many word processors use an extended 8-bit form of ASCII, and no two 8-bit forms are compatible. For conversion you must remove the extra bit, a job that can be done by many programs available from user groups. A few word processors store characters in EBCDIC rather than ASCII, in which case conversion is simple but may require an extra step.

When a raw document proves impossible to work with, you can often transfer a page image instead. A page image is the disk equivalent of the printed page, complete with headers, footers, and page numbering. Most full-function word processors let you make a page image (with the command "print to disk" or something similar). Page images are difficult to work with, since they have carriage returns at the end of each line and the headers and footers clutter up each page; boldface or other special type instructions are usually missing. But at least page images

by Cary Lu

are free of embedded formatting commands that can interfere with the receiving word-processing software.

A text-only document lacks all formatting information except paragraph ends and, sometimes, tabs. Most word processors can read a text-only document and thus save you from retyping the text, but you will have to reformat everything—often a long, tedious process.

The only truly satisfactory form in which to transfer a file is as a revisable document. It contains all the formatting information of the original file converted into a form that you can edit immediately with the receiving computer and software. Because programs differ in specific features, the formatting information may not be complete, but it preserves at least such essential parameters as the left and right margins, tabs, columns, line spacing, headers, and so on.

Although creating a revisable document is purely a software issue, the most comprehensive format conversion thus far has been built into disk converter boxes. A surprising number of companies offer these disk converters, which are mostly free-standing computers with multiple floppy disk drives able to read and write many different formats. In addition to a flexible floppy disk controller, the converters include format conversion software. The media conversion covers a far wider range of formats than any of the aforementioned pure software converters for the IBM PC. Many disk converters were originally developed for the typesetting market, to convert word-processing documents into typeset text.

Shaftstall, a typical dedicated conversion system, costs from $21,000 to $35,000; with accessories, it can read and write 3½-inch disks. The InterMedia system from England, distributed in this country by U.S. Lynx, uses a Zenith Z-100 computer as the host and can read 148 8-inch disk formats (it writes 89 of them) and 165 5¼-inch formats (it writes 108). The price is $15,000 including the Zenith micro. A price/performance leader among disk converters is Flagstaff Engineering's system, which costs about $2000 (without the IBM PC needed to run it). Unlike most disk converters, Flagstaff's uses DCA (described below) as its intermediate conversion format.

The company putting the largest effort into fully functional document conversion for the office is Keyword. The Keyword 7000 uses an IBM Personal Computer as the host and converts WordStar and MultiMate PC programs, as well as the most popular dedicated word processor formats; it costs $10,000 without the PC.

Disk converters are often the only way to deal with the most recalcitrant dedicated word processors—machines with unusual disk formats that lack communications capability. Such balky equipment is being displaced by general-purpose microcomputers that support full telecommunications and can use (or convert to) the IBM PC floppy disk format easily. So disk converters will be increasingly limited to exceptional situations as format conversion becomes merely a software problem.

If you have a way to hook your computers up to a telephone and a modem, you can get one of several service companies to do the format conversion *for* you. You transfer a file from the sending machine to the company's computer, which then converts the format and sends it back to your receiving machine. Prices can be modest; General Electric Information Services, for example, charges only $2 for the first page and $1.20 for additional pages. So far, though, GE supports only a few formats.

DCA attributes

Revisable-Form-Text

- Declare top and bottom margins
- Number pages and lines
- Specify space occupied by body text
- Specify page width and height
- Insert fields from external data records
- Include text from other documents
- Keep specified text together on the same page
- Spelling verification control

Final-Form-Text

- Top margin location
- Left margin location
- Line spacing
- Font definition
- Justify text
- Begin and end underscore
- Begin and end overstrike

Source: IBM document GC23-0765-0, Office Information Architectures: Concepts

IBM's DCA standard interchange format comes in two versions.

The key to text file conversion is a universal intermediate format, one understood by all programs. Many intermediate formats have been proposed and discussed for public distribution, but the market has already settled on IBM's Distributed Office Support System (DISOSS). Developed as a standard interchange format for IBM's office computer products, DISOSS employs two architectures: DCA (Document Content Architecture) and DIA (Document Interchange Architecture).

DCA specifies the format for transmitting text documents from one system to another. It defines page width, tabs, headings, and other attributes. DCA comes in two forms (see table)—Final-Form-Text DCA (FFTDCA) and Revisable-Form-Text DCA (RFTDCA).

DIA specifies the communications protocols for sending DCA files as a part of IBM's System Network Architecture (SNA). DIA covers not only the specific transmission structure but also the way requests are made for a file, and it can create a document library for multiple users. Although DIA specifications describe only text files, other file types can be included by extensions.

DCA and DIA are complex standards, and compatibility can be defined in many ways. Many computer manufacturers have announced support for at least part of DISOSS, usually DCA. Some companies, trying to hang on to their customers, support only the FFTDCA form, because they fear that using the RFTDCA form would make it too easy for their customers to change over to IBM or other RFTDCA-compatible products. Independent software developers may offer more complete DISOSS support than some hardware vendors.

Initially, at least for microcomputer users, the DCA portion of DISOSS is the most important. DCA is quickly becoming the lingua franca of office word-

Companies

Award Software (Crossdata), 236 N. Santa Cruz Ave., Los Gatos, CA 95030, (408) 395–2773
DataViz (MacLink), Box 1319, Norwalk, CT 06856, (203) 866–4944
Information Reduction Research (WP Toolset), 28 Ridgewood Rd., Concord, MA 01742, (617) 369–5719
Flagstaff Engineering, Box 1970, Flagstaff, AZ 86002, (602) 774–5187
General Electric, 401 N. Washington St., Rockville, MD 20850, (301) 340–4000
Keyword Office Technologies, 2047 Hamilton Ave., San Jose, CA 95125, (800) 227–1817
M/H Group, 222 W. Adams St., Chicago IL 60606, (312) 443–1222
Micro Solutions (Uniform), 125 S. 4th St., DeKalb, IL 60115, (815) 756–3321
Office Solutions (OfficeWriter), 5708 Odana Rd., Madison, WI 53719, (800) 228–0747
Samna, 2700 NE Expwy, Suite C-700, Atlanta, GA 30345, (404) 321–5006
Selfware (Convert), 3545 Chain Bridge Rd., Suite 3, Fairfax, VA 22030, (703) 352–2977
Shaftstall Corp., Box 50990, Indianapolis, IN 46256, (317) 842–2077
Soft-Switch, 200 N. Warner Rd., King of Prussia, PA 19406, (215) 768–9330
U.S. Lynx, 853 Broadway, New York, NY 10003, (212) 673–3210
Vertex Systems (XenoCopy), 6022 W. Pico Blvd., Suite 4, Los Angeles, CA 90035, (213) 938–0857

processing formats, used as the intermediate form between two otherwise incompatible systems. Microcomputer word processor support for DCA includes Samna, OfficeWriter, MultiMate, and IBM's DisplayWrite series. DCA support has been announced for WordStar and Microsoft Word. In each case, bidirectional RFTDCA conversion capability either comes with the program or is a low-cost extra. The M/H protocol converter for the Wang also reads and writes RFTDCA. The $75 WP Toolset performs RFTDCA-to-ASCII conversion and includes useful but limited conversion utilities for many popular microcomputer word-processing programs.

There are several expensive routes to DCA: The Soft-Switch DCA converter (used by GE for its conversion service) and Samna/Dart for IBM mainframes cost from $50,000 to $70,000. Such programs work only on systems that can talk to the mainframe, hence ruling out many dedicated word processors. Some disk converters are adding DCA to their supported file formats.

Inevitably, no standard such as DCA can deal with every possible feature. And many traditional word processors do not support every DCA feature, although the discrepancies are not always severe. Wang, for example, does not support backspacing and overstriking with an arbitrary character that is part of DCA. Documents created for eventual DCA conversion should avoid using special features.

Although matters have improved, the conversion problem will most likely get worse again.

DCA's main problem is that it was designed for traditional word processing; it conceives of text in terms of daisywheel printers, providing for changing print elements and pitch but not supporting new features found on the most modern products, such as the type fonts and sizes on the Macintosh and advanced laser printers. Since DCA is extensible, these features could be added, but they might not be standardized. Such extensions are making DCA a moving target; IBM itself continues to add features. According to Keyword, though, DCA handles only about 600 attributes, while Keyword's own conversion system (a superset of DCA) specifies 1700 attributes. All in all, DCA isn't great, but it is much better than a straight ASCII file.

The U.S. Navy has sponsored another conversion format, DIF (not to be confused with the DIF developed by Software Arts for VisiCalc). The Navy DIF is gaining use in government agencies but supports only the most basic formatting information.

After any conversion, you must often do some clean-up work. In effect the document is degraded during the conversion because of lost features. As a result, even revisable text files are often impractical for routine use; most users who need to convert a file should probably do it just once, rather than bounce the file back and forth between two systems. However, the best conversion systems can sometimes make multiple conversions practical. Keyword helps out by specifying which attributes can't be converted.

With all present file conversion techniques, you must run a program to do the conversion. In the future, a file server on the network could check which program had requested the file and automatically convert it. Although matters have improved in the past year, the conversion problem will likely get worse again. As dedicated word processors slowly give way to general-purpose microcomputers, a new class of graphics composition systems is emerging, able to perform typesetting functions interactively and to incorporate graphics. These products, which have much more complex document formatting than any word processor, will open a whole new can of worms. □

Cary Lu is microcomputer editor of HIGH TECHNOLOGY.

PAVING THE WAY FOR SPACE TUGS

Reusable rockets will take payloads to higher orbits or the moon

NASA is preparing to take yet another fairly large leap for mankind. Last July, the agency's Marshall Space Flight Center in Huntsville, Ala., awarded two $1 million contracts for initial studies on a space tug, or reusable orbital transfer vehicle (OTV), which would carry large payloads to geosynchronous orbit and beyond. The rocket, scheduled to begin service in 1995, will most likely be launched from the space station, although it may instead be based on the ground and lofted into orbit by the shuttle.

The Space Shuttle itself can fly no higher than a few hundred miles. Yet a great deal of traffic, particularly in communications satellites, must go to higher orbits, notably the 22,300-mile geosynchronous orbit that keeps a satellite hovering over one spot. To meet this need, NASA is relying on a variety of upper stages that fit into the shuttle's payload bay.

For the future, though, NASA sees several disadvantages in these stages. They can't loft large or bulky satellites. They can't be based at the space station. And they can't support such future NASA hopes as enlarging the space station or, later, returning to the moon. By contrast, the reusable OTV could do all these things.

The contracts from NASA-Marshall therefore stirred a lot of interest within the aerospace industry. They went to Boeing Aerospace in Seattle and to Martin Marietta in Denver. General Dynamics (San Diego) lost out in the bidding, but it deemed this study so important that it put up $1 million for its own effort. In addition, a smaller effort is under way at NASA's Johnson Space Flight Center in Houston.

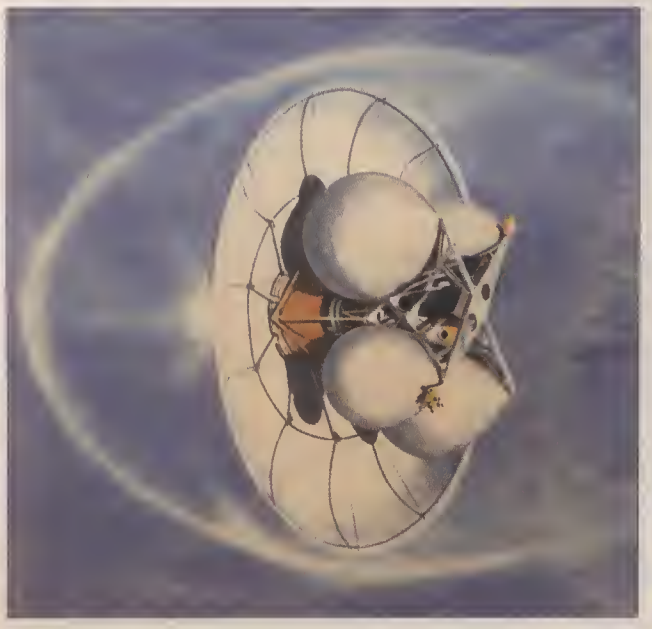
These studies, lasting 12–15 months, aim at nothing so advanced as full-fledged designs ready for construction and test. Instead, their goals are to weigh the costs and benefits of a variety of features that NASA considers desirable in a future OTV.

One OTV feature considered particularly important by NASA is fuel economy. "A pound of propellant has become very dear," says Dana Andrews, manager of Boeing's study; hauling a pound of propellant in the shuttle costs $1400. Thus a question confronting the OTV contractors is how to get the most performance from that pound. Rocket performance is defined by a meausre of fuel economy called specific impulse. It is the length of time a pound of propellant can last while constantly producing a pound of thrust.

Boeing is studying the use of liquid hydrogen and liquid oxygen as propellants for the OTV, because they would yield the best specific impulse—theoretically as high as 520 seconds. However, liquid hydrogen boils at −423° F, a mere 37° above absolute zero. As a result, it would present a significant safety hazard for the OTV, which must store its propellants in space for long periods.

Martin Marietta has proposed the use of propellants that remain liquid

by T. A. Heppenheimer



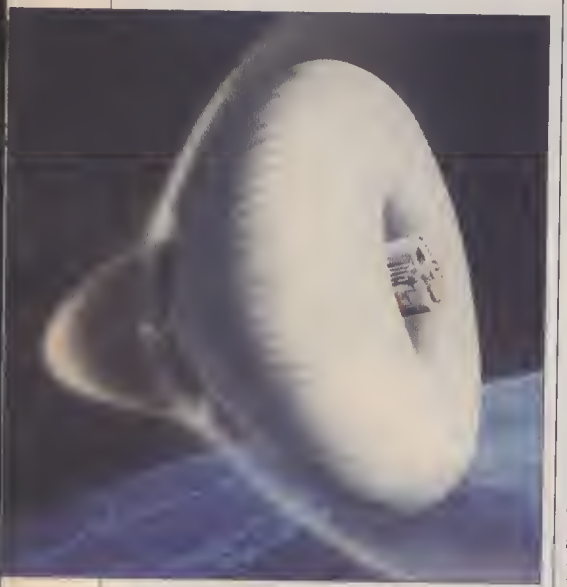
Early versions of the reusable OTV will be based on the ground and carried to orbit by the shuttle. In this Martin Marietta concept, the motor fires forward through the umbrella-like aerobrake, which furls for storage on the shuttle.

Later OTV versions will be based at the space station. This General Dynamics concept features a fixed aerobrake. The payload—a communications satellite—is forward of the propellant tanks.

at room temperature. These fuels—monomethyl hydrazine and nitrogen tetroxide—have powered several rockets built by Martin Marietta, including the Titan launch vehicle and the Viking spacecraft to Mars; the company would obviously like to draw on this experience. These fuels are more than 65% heavier than hydrogen-oxygen, however, while delivering a specific impulse of only 342 seconds.

But NASA believes that it may have developed a solution to the liquid hydrogen problem. The agency's Lewis Research Center in Cleveland has devised a multilayer insulation that would allow hydrogen to be "stored in space for years," says Pete Wanhainen, a NASA-Lewis engineer.

The insulation consists of some 30 layers of thin aluminized Mylar or Kapton plastic. A fuel tank is built like a Thermos flask, with an evacuated double wall; the insulation forms a blanket inside the wall. The plastic layers are separated by a silk-net layer and are held together with widely spaced plastic pins. In space, heat can reach the fuel by only two routes, but both are highly inefficient. If the heat follows a tortuous path by way of the plastic pins, the low heat conductivity of the plastic allows very little to get through. And if it radiates from layer to layer, the aluminum coating on each sheet reflects nearly all of it. Thus, with the aid of a shadow shield to keep a fuel tank in the shade, hydrogen may remain liquid for a long time. This arrangement has yet to be tested in space, but it has worked in a large vacuum test chamber at NASA-Lewis.



Boeing's OTV concept features a deployable "ballute." The rocket fires forward to produce a pointed plume within the oncoming airflow, controlling the spacecraft's drag.

Even if these propellants can be stored safely in space, can they be transferred to the OTV in a low-gravity environment? "We don't know right now if we can control the flow to get it where we want it to be," says Donald Saxton, manager of NASA-Marshall's OTV studies. For example, bubbles of gas may form in a channel and interfere with the flow. NASA-Lewis is therefore developing an experimental propellant management system for in-orbit refueling that will fly aboard the shuttle in 1987. In this experiment, astronauts will attempt to transfer liquid hydrogen between two small tanks.

Of the rocket motors available for today's upper stages, Pratt & Whitney's RL-10 engine has the best fuel economy. Yet it extracts only 444 seconds of specific impulse from its hydrogen-oxygen propellant—well below the theoretical maximum of 520 seconds. The OTV goal is to increase the specific impulse to more than 490 seconds.

The way to this goal lies in increasing combustion chamber pressures, which will allow the rocket motor to be shrunk. The throat, the wasp-waisted part of the nozzle, can thus be made narrower. The nozzle itself can then flare more sharply, permitting the rocket exhaust to expand more—and this expansion is what will give the extra seconds. However, these seconds stand to be hard-won. To produce a combustion chamber pressure of 400 pounds per square inch, Pratt & Whitney's RL-10 employs a turbopump that spins at 30,000 rpm. Advanced engines proposed for the OTV would require chamber pressures as high as 2000 psi, necessitating turbine speeds of up to 200,000 rpm.

Such speeds are "well beyond the state of the art," according to Sol Gorland, a section head in NASA-Lewis's rocket technology group. The fastest turbopump yet tried was in Rocketdyne's Advanced Space Engine, which ran on a test stand in 1978. It reached 95,000 rpm—briefly—and the engine achieved 478 seconds of specific impulse. This year Rocketdyne expects to test a new engine capable of 110,000 rpm and 481 seconds, still well below NASA's OTV requirements.

An OTV will be used about 30 times. Thus an extensive program of test and development will be needed to assure long life. Engine development alone will cost $350–500 million.

Is it worthwhile to build a new engine? A 10-second increase in specific impulse boosts the payload capacity by about 4%, which could be counted as a marginal advantage. The propellant saved is closer to 2%. Still, at shuttle freight rates, these modest savings might pay back the cost of engine development in only a few years. "That's why we would like a new engine, as advanced as we can afford," says Boeing's Andrews.

If NASA runs into budget problems, it can always employ an advanced version of an existing engine, thereby reducing development costs substantially. For example, developing an advanced version of Pratt & Whitney's RL-10, which was designed in the late 1950's, would cost about $100 million, says Andrews.

In either case, the OTV would be a boon to the United States' major rocket engine manufacturers, which are currently suffering from a lack of new business. Besides Pratt & Whitney, Aerojet and Rocketdyne could be expected to compete for any contract that NASA might issue to develop an engine for the OTV.

Once it has reached a high orbit, the OTV must be able to return to the low orbit where it can meet the shuttle or the space station. When returning from geosynchronous orbit, the OTV arrives with some 7000 feet per second of excess velocity. If it used rocket thrust to cancel this excess velocity, it would have to carry a reserve of propellant whose weight would cut the payload by half. Consequently, the OTV is to use aerobraking, relying on atmospheric drag to slow its speed.

This maneuver will be tricky. The craft will swing through the upper atmosphere at an altitude of some fifty miles, relying on the Global Positioning Satellite network (which broadcasts reference signals for navigation) to achieve an accuracy within 200 feet. This is necessary to keep the OTV from braking either too little or too much. But the atmosphere at such altitudes is quite variable and unpredictable. So the OTV concepts of NASA-Johnson, General Dynamics, and Martin Marietta will generate lift, to fly up or down to the altitude that gives the proper deceleration. Boeing's concept will vary its drag, as an alternate way of

ensuring proper braking.

NASA-Johnson's proposed aerobrake is the most conservative. Called a raked cone, it resembles an off-centered saucer with thermal protection tiles on one side. These tiles, being developed at NASA's Ames Research Center, will face higher temperatures than the tiles used on the shuttle.

The asymmetry of this shape allows the space tug to generate and control a modest amount of lift by rotating about its center of gravity. The concept is directly descended from the Apollo command module, in which the center of gravity was offset.

By contrast, Martin Marietta and General Dynamics propose an aerobrake resembling a large umbrella, supported by ribs of graphite-polyamide composite. This "lifting brake," based on the same principle as the rocket cone, would be as much as 50 feet across. The most daring aerobrake concept is the "ballute" proposed by Boeing—a ring-shaped balloon that would act as a parachute, completely surrounding the hull of the OTV. Boeing's Andrews claims that this device would be 1000–1500 pounds lighter than the lifting brake. It inflates with seven pounds of hydrogen.

However, the ballute's aerodynamics are chancy. It can generate no lift. Instead, the space tug's drag is varied by the engine, which fires forward through the hole in the ballute's ring. At a thrust of 100 pounds, the engine merely dribbles a flow of gas over the ballute, helping to keep it cool but leaving its drag at maximum. At a thrust of 1000 pounds, the engine shoots forward a sharp plume, or "aerospike," which acts like a streamlined aircraft nose. This reduces the drag by 90%. The hope is that by turning the engine off and on, the drag can be well controlled. But this approach has not been adequately tested. For now, at least, NASA prefers the lifting brake.

Both the ballute and the lifting brake would require thermal protection. At Ames Research Center, Paul Sawko has been working with Woven Structures, a firm in Compton, Cal., to develop ceramic insulating blankets capable of withstanding reentry temperatures of 2200° F. Although ceramics may seem an unlikely choice of material for a blanket, several manufacturers have managed to turn them into pliant fibers. Japan's Nippon Carbon Company, for example, produces silicon carbide—commonly used as an abrasive—in the form of a yarn; it is marketed by Dow Corning under the name Nicalon. Similarly, 3M (St. Paul) has a ceramic fiber known as Nextel, made from aluminum borosilicate.

These fibers can be prepared in short lengths and matted together to form a felt. They can be mixed and sintered to produce tiles, such as those required by Johnson Space Center's aerobrake. Or, in a more demanding application, they can be prepared as long strands and woven into fabrics. Sawko's blankets start with an upper layer or two of Nicalon or Nextel. The bottom layer is a fabric of Kevlar or fiberglass. Between these layers are triangular pockets filled with a batting of Nextel or of silica from Manville Corp. (Denver). Boeing's ballute calls for a similar arrangement: Kevlar on the inside for strength, then a layer of temperature-resistant Viton rubber for gas-tightness, then a half-inch insulating layer of Nextel felt, with an outer layer of Nicalon cloth to face the heat of reentry. A 50-foot ballute would weigh only 1200 pounds.

In addition to engines and aerobrakes, many other systems and facilities must be developed. For example, the space station will have to be expanded considerably. There will be an array of propellant tanks, holding fuel for several missions; there will also be an OTV hanger, which may be built as an enclosed, pressurized facility, full of robots and manipulator arms. In some space station concepts, these facilities are larger than the basic set of modules now proposed for launch in 1992.

In addition, the OTV will need "smart diagnostics." There will be no opportunity to follow shuttle-type procedures in readying OTV for a launch. The Shuttle needs 1200 people and several weeks for this preparation; the OTV will have only three people and a few days. Such chores as monitoring and interpreting OTV instruments will therefore be handled by expert systems. A computer will switch in backup systems or prepare instructions for the maintenance crew.

Still, one is entitled to ask, is all this new technology really necessary? After all, the potential of today's expendable upper stages is far from being wrung out. The Centaur, with two RL-10 engines burning hydrogen and oxygen, can carry 10,000 pounds to geosynchronous orbit—and will not fly aboard the Shuttle till May 1986. And even though the reusable OTV will eventually double this payload, it could lift even more if, like the Centaur, it were built as an expendable rocket. But NASA is developing the OTV not merely to haul tomorrow's communications satellites into orbit. It may also be called upon to ferry people and materials to the moon.

A two-stage version of Johnson Space Flight Center's OTV carries elements of a lunar base toward the moon. The large heat shield shelters propellant tanks and rocket motors.

"That's exactly what it is designed for," says Barney Roberts, manager of NASA-Johnson's OTV study. Joe Keeley, director of Martin Marietta's study, concurs: "The driver mission on the requirements would be manned and unmanned flights from the space station to a lunar base, starting in the year 2006." The cost of this lunar base has been projected at $50–90 billion. To build it, pairs of OTVs would be launched as two-stage vehicles, delivering 80,000-pound loads to lunar orbit. Included in these loads will be the landing rockets that will carry components for the base to the lunar surface.

NASA estimates that development of the reusable OTV itself would cost as much as $2 billion. So expensive a project is certain to be scrutinized by Congress and the White House. If their approval is forthcoming, however, and the OTV lives up to its promise, the U.S. could gain a versatile new mode of space transportation. □

T. A. Heppenheimer, a writer in Fountain Valley, Cal., has a PhD in aerospace engineering.

SCIENCE/SCOPE

A new technique may expand the use of lasers in commercial and military applications. The approach, called optical phase conjugation, is considered a major advance in optics because it offers a solution to distortion problems that have limited the use of lasers. When a laser beam passes through a turbulent atmosphere or a severely strained optical component, the beam is distorted and the information it carries is degraded. The Hughes Aircraft Company technique, however, forces the laser to retrace its path through the distorting medium so the beam emerges free of distortion. The method eliminates the need for complex electro-optical and mechanical components to correct the distortions.

Pilots of future aircraft may rely on artificial intelligence systems to help them assess combat situations and take appropriate offensive or defensive actions. Hughes engineers are conducting studies for the U.S. Air Force on potential uses of artificial intelligence for fire control and battle management. One focus is how to identify targets automatically and present this information for a pilot's use. Another aspect involves tactical analysis, including decision-making that advises a pilot whether to attack, flee, apply electronic countermeasures, or fly low-altitude routes. New automation techniques may be necessary for pilots to cope with the fire control systems that now are being designed for the next generation of military aircraft.

The first attempt to sample the atmosphere of an outer planet, NASA's Project Galileo will journey 750 million miles to Jupiter this decade. The mission will consist of two spacecraft, an orbiter and a Hughes-built probe. Six instruments inside the probe's descent module will assess the structure and composition of the atmosphere, determine the location and structure of clouds, calibrate a precise ratio of hydrogen and helium, and measure lightning, radio emission, and energy absorption. The probe will transmit data to the orbiter for relay to Earth. Project Galileo will be the first interplanetary vehicle launched from the space shuttle. The launch is set for May 1986 and arrival for August 1988. Four Hughes-built probes explored the atmosphere of Venus in 1978.

High-energy laser pointing and tracking systems are among the advanced electro-optical systems supported by the Albuquerque Engineering Center in New Mexico. The center's scientific disciplines include physics, optics, mathematics, lasers, image processing, electro-optical control systems, and computer science. Programs involve electro-optical sensors for strategic military applications, including work performed at the U.S. Air Force Weapons Laboratory at Kirtland Air Force Base and the White Sands Missile Range. The Hughes center is expected to expand from its current staff of 42 highly trained professionals to greater than 100 over the next three years.

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GO SAIL A KITE!

Innovative sailors are finding more efficient ways to harness the wind

A kite sail consisting of a ladderlike stack of flexifoils propels the catamaran Jacob's Ladder *at speeds of up to 25 knots. Inset: a train of delta-wing kites.*

In addition to being fascinating toys, kites have practical applications in aerial survey and photography, meteorology, advertising, and crop pest control. The Canadian timber industry employs hybrid kite/dirigibles to lift logs from otherwise inaccessible sites. And two close relatives of kites—controllable-descent parachutes and hang gliders—have become popular recreational craft.

One of the oldest uses of kites is for propulsion. The ancient Samoans developed kite-propelled canoes. In 1826, George Pocock patented his Char-volant, a light carriage drawn by two kites and capable of reaching 32 miles per hour. And in 1903, kites attached to a 13-foot collapsible boat pulled early flight pioneer Samuel Franklin Cody across the English Channel. Today, yachtsmen are again becoming interested in kites for propulsion because of their high efficiency and their ability to convert wind energy into aerodynamic lift without auxiliary power.

Kite sails can improve the speed of racing yachts by reducing the drag on the hull caused by its displacement of water as it moves along and by the friction of water against the hull. In a conventional yacht, the force of the wind is concentrated in the center of the sail area, several feet above the deck. As a result, the boat tends to lean over, or heel, sharply in strong winds, requiring good form stability and heavy ballast to avoid capsizing. In contrast, a kite sail is attached by a direct line to a fitting on the deck. Since the wind force is concentrated at deck level rather than several feet above, heeling is greatly reduced, and the boat can maintain adequate stability with less ballast and a lighter, streamlined hull.

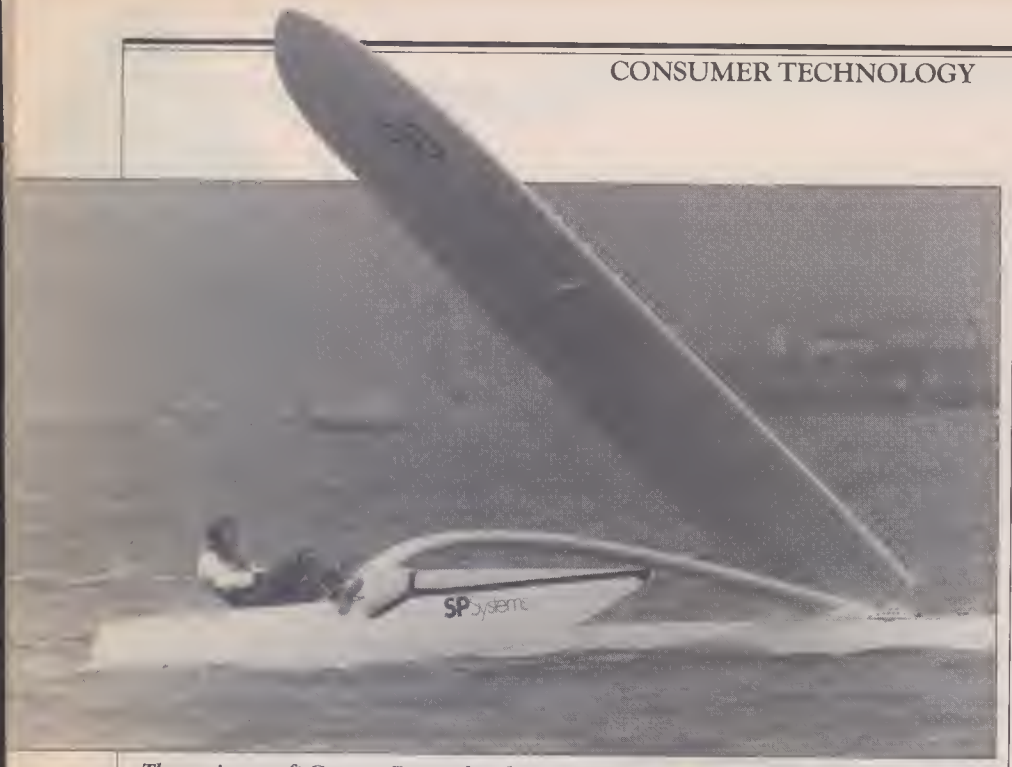
A second advantage of kite sails over ordinary sails is that they generate lift as well as forward motion. In a conventional yacht, the wind force can be divided into two components: a side force that drives the boat forward and laterally at the same time, and a down force that presses the boat deeper into the water, increasing its resistance to forward motion. Although a kite sail generates an equivalent side force, the vertical force component is upwards rather than downwards, lifting the boat out of the water and reducing its displacement and drag.

Finally, the heeling force on a conventional yacht must be counteracted by the tension of the mast shrouds and stays, which in turn bend, pull, and compress the mast and hull. Thus the mast and hull must be strong and heavy enough to resist considerable stresses. Because a kite sail is in simple tension, the hull can be built much lighter, further reducing drag. Indeed, a future kite-powered yacht might dispense with a hull entirely, consisting of a keel with the crew suspended in a pod above the water.

Despite the theoretical advantages of kite sails, some major obstacles must still be surmounted before they become truly practical. Perhaps the greatest challenge is aerial handling. Virtually any type of kite can be flown straight downwind on a single line, with the yacht being towed to either side. But a yacht must also be able to tack, or sail into the wind at an angle—a task that is difficult or impossible with an ordinary kite.

This type of operation requires more efficient kites that can fly at angles close to windward, such as a delta-wing kite with dual control lines. Unfortunately, the more efficient kites are also highly sensitive to small variations in wind direction. If the wind is fluctuating rapidly, the kite tries to dive, spin, and crash, and must be tended almost constantly. Moreover, a kite boat cannot switch from one tack to another by turning into the wind. Instead, the kite sailor must first sweep the kite downwind and then back upwind on the other tack, a maneuver similar to that once performed by square-rigged ships.

by Steven Callahan



The racing craft Gamma Pacemaker *has a canted foil, a wing tilted into the wind. The foil acts like a kite attached to the deck, generating lift and forward motion.*

A kite design that achieves an optimal balance between stability and efficiency was designed by Andrew Jones and manufactured by Merry & Jones (Haverhill, England). It consists of several rectangular kites, or "flexifoils," stacked in a ladder configuration called a kite train. This system provides good control and tacking ability, and it is largely self-correcting. If one foil stalls, the train loses lift and drops earthward, increasing the angle at which the wind strikes the other foils and generating more lift. In 1982, British racing sailor Ian Day achieved the world speed record of 25.03 knots in his flexifoil-driven catamaran, *Jacob's Ladder*. And in 1979, British sailor Keith Stewart used another type of kite train, consisting of delta-wing kites, to cross the English Channel.

Kite trains will probably become more popular than large single kites because they are more forgiving and easier to handle. For example, reefing—reducing the amount of sail area in heavy winds—can be accomplished by removing kites from the train or by using smaller kites. Kite trains can also be flown at fairly high altitudes, where the wind is stronger and often travels in a different direction from surface winds. By exploiting these shearing winds, a kite yacht would be able to sail closer to windward than a conventional yacht. In 1978, Gordon Gillett, sailing a Sunfish propelled by a train of delta-winged kites, steered within 45° of the wind direction.

Launching a kite sail is another major problem that remains to be solved satisfactorily. Ian Day anchors *Jacob's Ladder* offshore, launches the flexifoil from the ground, and then ups anchor and sails away; if the kite crashes, the boat must return to shore. But kite sails intended for long voyages must clearly be capable of launch at sea. One design that can be launched from the surface of the water is the Stewkie Semi-Sail, an inflated kite sail developed by Stewart and manufactured by Stewkie Aerodynamics (Melbury Osmond, England). The Semi-Sail—which is semicircular in plan and airfoil-shaped in section—has dual control lines and generates large amounts of lift. Other launching methods under development include the use of floating pylons to support the kite on the water surface, and the use of small lifting kites to carry larger driving kites aloft.

A close relative of the kite sail is the canted foil, an ordinary sail tilted to windward that behaves like a kite attached to the deck, generating vertical lift as well as forward motion. Wind surfers exploit this effect by leaning backward to tilt the flexible sail into the wind. Indeed, expert wind surfers often achieve so much lift while wave hopping that they soar into the air; they then use the sail as a near-horizontal wing to glide back down to the water surface. Because the canted foil reduces drag, expert wind surfers have achieved speeds in excess of 25 knots, far better than their predicted optimal performance.

Canted foils have also been tried out on full-size racing yachts. A mast that can be tilted to windward was tested in 1984 on the 85-foot French racing yacht *Charles Heidsick*. A canted foil may even take the form of a solid wing; a prototype system was demonstrated recently on a racing catamaran called the *Gamma Pacemaker*. Since canted foils eliminate or minimize the launching and control problems associated with kite sails, they will probably become standardized and adopted for some vessels on a production basis within the next 5–10 years.

Although the use of kite sails for primary boat propulsion is still in its infancy, a more immediate marine application is for emergency use. Should a boat lose its mast or a powerboat its engines, compactly stowed kites could provide effective jury-rigged propulsion systems. Indeed, English long-distance sailor Kitty Hampton has used kites to pull her 38-foot cruiser at several knots, and inflatable Stewkie Semi-Sails have successfully propelled a small tanker.

Emergency kites may also serve to increase the visibility of life rafts, which are difficult to spot even in moderate seas, aiding in the rescue of shipwrecked sailors. During World War II, the Gibson Girl box kite served as a highly visible emergency beacon and carried a radio antenna aloft to extend considerably the range of transmission. The inflatable Stewkie Lifekite is designed for emergency use, and next-generation designs will incorporate radar reflectors. Eugene Murphy and Bill Watson of Lifesaver Industries (Santa Monica, Cal.) are developing an emergency kite that will be stable in winds of up to 50 knots.

Kite sails may eventually become as sophisticated as gliders are today, with tails and flaps controlled from the ground by strings or by remote control, allowing boats to sail closer to windward. And just as conventional racing yachts carry large inventories of sails such as Kevlar-reinforced mainsails, spinnakers, and genoas, kite yachts will carry several types of kites specialized for downwind or upwind sailing. If the price of oil rises dramatically, kite sails may even become economical for large-scale marine applications, such as towing offshore oil rigs and propelling a new generation of wind-powered merchant ships. □

Steven Callahan is a naval architect, sailor, and writer living in Ellsworth, Me. He and some friends plan to cross the Atlantic next year in a kite-propelled yacht.

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Freeze processes may answer an age-old prayer

Long before medieval alchemists struggled to turn lead into gold, thirsty sailors pondered a conversion almost as tricky—that of drawing unlimited supplies of fresh water from the ocean. While there are plenty of methods for accomplishing the feat on a small scale, the energy required to run a commercial desalination plant has usually made such projects extremely expensive.

That accounts for the appeal of freeze desalination. The simple, low-energy process is based on the fact that as water freezes, contaminants are automatically excluded from the crystal structure. Despite persistent design problems during the past 30 years, the method is still regarded as an appealing way of producing fresh water from the sea. Unlike reverse osmosis, a membrane separation process that accounts for almost 30% of the world's 2200 desalination plants, freeze desalination involves minimal corrosion and fouling and requires no pretreatment. The advantage over the energy-intensive distillation process, which accounts for about 70% of all desalination plants, is even more attractive. While it takes 1000 Btu's to boil a pound of water, only 144 are needed to freeze it.

One of the most promising of the new freeze processes was conceived by physicist Ted Taylor and is now being developed by his company Nova (Gaithersburg, Md.). While the process is aimed primarily at desalination, Taylor claims it may be applicable to wastewater treatment as well.

Basically, it works like this: On cold days (29° F or less), water is pumped from the ocean and sprayed over a plastic-lined holding area. A 70-foot-square area was used in the first field test, but almost any size would do. About 10% of the spray freezes; since salt and other impurities are not carried into the crystal structure, the resulting porous bed consists of pure ice. (A salty residue remains on the ice surface, but is washed away by the initial melt.) The remaining liquid brine percolates through the ice pack and returns to the sea. The ice pack continues to grow until warmer weather arrives, at which time the melting ice becomes fresh water.

Salt water is sprayed onto the holding area at Nova's Long Island demonstration site. Salt is ejected from the water as it freezes, reducing the concentration from 30,000 ppm to 10 ppm.

Taylor claims that the water's salt content drops to below 500 parts per million (ppm)—safe for drinking—after only 10% of the ice has melted. Further melting brings the concentration to 10 ppm. The salt content of ordinary seawater is 30,000 ppm.

The major capital expense for the spray process is the land required for ice storage. The maximum practical ice thickness is 100 feet, and Taylor estimates that the land area required is similar to that for a reservoir of the same capacity. And since nature provides both refrigeration and melting, the only energy required is that needed to run the pumps, which is far less than the energy needed by any other desalination process.

Although the spray concept itself is not patentable, Taylor is hoping for patent protection on some of the details of his system. The most sensitive part of the process is the control of the spray: If the droplets are too small, they will drift away from the holding area; if they're too large, they won't freeze. Finding the happy medium is as much art as science.

Timing and layout are also crucial. The holding area must be cool enough so that the initial ice needed for the porous bed doesn't melt prematurely. And the spray must be evenly distributed to assure a uniform, space-efficient ice buildup.

The principles of Taylor's process have already been proved in laboratory tests, and a demonstration project in Greenport, Long Island, has been underway for two years. The location typifies the water supply problems the nation is facing in the years to come—a heavily populated area dependent on a single aquifer that is stretched to the limit and is suffering from saline and toxic-chemical intrusion.

The demonstration is being funded by the New York State Energy Research and Development Authority (NYSERDA), the New York Power Authority, and the village of Greenport. Taylor notes that 200 tons of ice were created during the winter of 1984–85 (about 48,000 gallons of potable water).

by Ira P. Krepchin

Meanwhile, Nova and Greenport have submitted a joint proposal to NYSERDA for the construction of a much larger facility—about an acre and a half, yielding 10 million gallons of water a year. If approved, the new unit could be running by the end of 1985, and would supply fresh water during next summer's peak use periods.

But at what price? Taylor concedes that the primary goal of the Greenport plant was to demonstrate the principles regardless of cost. "But we've set a target price of $1.25 to $1.75 per 1000 gallons," he says. That range is competitive with other new water sources on Long Island, and is considerably less than the $4 or more per 1000 gallons of the nearest desalination competitors. One way in which Nova might cut costs is by implementing a seeding procedure that would allow the formation of larger ice crystals and increase the percentage of water that is frozen to 30–40%, thus reducing the pumping energy required.

Taylor claims that his company's process could easily be extended into wastewater treatment, at least in the 44 states in which the thermometer falls sufficiently below the freezing mark during the winter. The challenge for Nova is to prove that the process works equally well in both situations: It's much easier to reduce the concentration of salt in seawater from 30,000 ppm to 10 ppm than it is to reduce wastes from 1 ppm to 10 parts per billion, the level required for many water treatment processes.

A commercial version of Nova's spray-freeze process will be developed within three years, says Taylor—probably in a seashore community with water problems (such as Long Island, Cape Cod, or Atlantic City). But he sees the concept eventually being used to clean and replenish contaminated aquifers throughout the Midwest. Several tests are now underway to demonstrate the principle.

Nova isn't the only company experimenting with freeze desalination. Several other methods have arisen during the past decade; most of them fall into one of two design types: the direct-contact type, in which a coolant is mixed directly with the water, and the simpler but less efficient indirect-contact type, which uses a heat exchanger to cool the water.

There are two types of direct-contact freezing: vacuum and secondary refrigerant. In the vacuum process, precooled water is sprayed into a vacuum chamber, where some of it flashes into vapor, removing enough heat to create an ice/brine mixture in the remainder. Both Carrier and Colt Industries built pilot plants of this sort in the late 1960s (under contract to the federal government's now defunct Office of Saline Water, or OSW), but the systems were too complex and costly.

Nova's Taylor says that his Long Island pilot desalination plant already produces 48,000 gallons of fresh water per year. He hopes to boost the yield to 10 million gallons and cut the price to half that charged by other plants.

In the secondary refrigerant process, a water-immiscible liquid chemical such as butane or a halocarbon is injected into the brine. As the refrigerant boils, it removes heat from the brine and causes the formation of ice crystals. The main problem with this method is that the refrigerant must then be separated from the water—a complex and difficult step.

Indirect-contact processes also have problems. For one, crystals often adhere to the walls of the heat exchanger as the saline solution freezes—much as frost builds up in an icebox—increasing the overall resistance to heat transfer. Early designs used scraper heat exchangers, in which the walls were mechanically scrubbed to remove the ice, but these proved to be very expensive. Newer surface treatment techniques have resulted in nonstick walls and have eliminated the need for scrapers.

One such process was developed by Chicago Bridge & Iron (CBI) in 1978. The project was subsidized by the federal Office of Water Research and Technology (the successor to OSW). A laboratory-scale, 6000-gal/day plant is currently being tested at the company's Plainfield, Ill., facility. CBI has also recently installed a 50,000 gal/day plant in Yanbu, Saudi Arabia.

John Andrepont, CBI program manager, says that the process features a unique electropolishing treatment that yields a very smooth heat exchanger surface. A "falling film" freezer design—in which a film of brine flows on the tube surface as it cools—also helps keep the heat exchanger free of ice. Even so, the system is currently too expensive to compete with reverse osmosis for seawater desalination, says Frank Reynolds, CBI's marketing spokesman. But for industrial applications, in which the source water would foul membranes or distillation equipment, CBI's system has a distinct advantage.

Eutectic freezing is yet another freeze desalination method. (In physical chemistry, a eutectic solution is one in which the composition varies with temperature.) The seawater is cooled to below zero, at which point it becomes pure ice and salt crystals—instead of a concentrated brine, as in other methods. The advantage of eutectic freezing is that no brine is discharged to the environment; thus the method is ideal for the production of irrigation water (in which a salty effluent would contaminate groundwater). The disadvantage is high power consumption. Both Avco (Everett, Mass.) and Fluor (Irvine, Cal.) have worked with eutectic freezing, but neither has yet developed a commercial system.

Nova's Taylor, of course, is confident that his big new plant on Long Island will soon prove to be an economical alternative to today's commercial desalination methods. If he's right—and if nature doesn't hand him a surprise in the form of an unseasonably mild winter this year—he could play an important role in quenching a part of the world's 3-billion-gallon-a-day thirst. □

Ira P. Krepchin is a Boston writer and engineer. He holds a master's degree in mechanical engineering from MIT.

PERSPECTIVES

Engineering unity: more hard times

Doctors have the American Medical Association, lawyers the American Bar Association. Among the professions, engineers have conspicuously lacked a strong central organization. Now the latest attempt at uniting the fifty engineering societies in the U.S., the American Association of Engineering Societies (AAES), is scrambling to avoid the failure that befell its several predecessors. This summer, for example, AAES moved its headquarters from New York to Washington, D.C., in an effort to increase its influence on public policy.

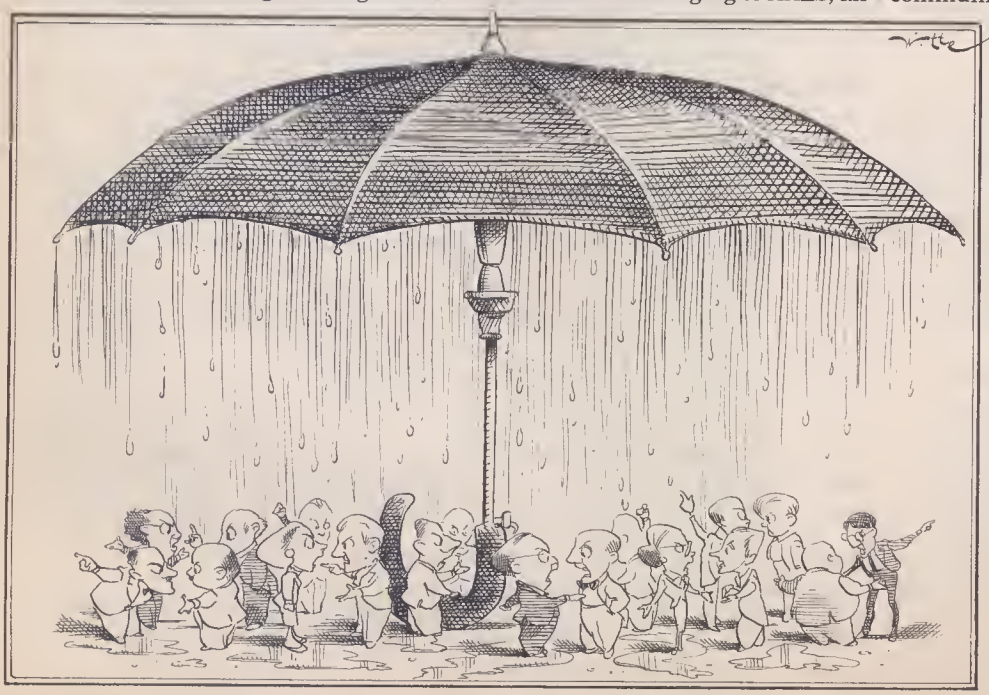
The AAES was formed in 1980 by the five largest engineering societies—the Institute of Electrical and Electronics Engineers, the American Institute of Mining, Metallurgical, and Petroleum Engineers, the American Society of Civil Engineers, the American Society of Mechanical Engineers, and the American Institute of Chemical Engineers. Originally, AAES was to be an umbrella organization, acting as a single source for information on engineering-related issues. But it is now being radically scaled back to fit a new role as "coordinator" among existing societies, which will continue operating more or less as before. AAES was weakened in this way largely because "too many of the societies don't want to surrender turf," says Carl Frey, a consultant who is studying the utilization of engineers for the National Science Foundation and the Defense Dept.

It was decided early on, for example, that the association should serve as the engineering profession's Washington voice, testifying before congressional committees on technical issues. But barely was the ink dry on these plans when the National Society of Professional Engineers, which represents licensed engineers of several disciplines, resigned in protest. The society had joined AAES with the understanding that it would serve as the new organization's informal Washington branch. "NSPE has acted as the engineers' lobbying organization since 1934," says executive director Donald Weinert. "We saw little justification in supporting an association that duplicated our own efforts."

That departure triggered many others, and AAES's original membership of 43 societies dwindled to 15. As support for the new society waned, its budget was cut in half and most of its staff resigned or were removed. Many of the societies that quit complained about the cost of belonging to AAES, an objection that can also be read as an unwillingness to give up control over funds that would go toward a similar goal whether spent by an individual society or by AAES. Some also took issue with policies AAES had not formalized—claiming, for example, that AAES would support unionization of engineers.

Meanwhile, the absence of a unifying organization raises barriers between engineers wishing to exchange information and gives the profession a diminishing voice in national affairs. For example, no one is asking engineers as a group whether President Reagan's Star Wars plan is feasible, even though engineers would ultimately be its designers and builders. "There is no voice for engineering," says Robert Frosch, General Motors vice-president for research and previously NASA administrator and Secretary of the Navy.

A wide-ranging assessment of current engineering issues published last spring by the National Research Council concluded that many of the problems engineers face stem from "poor comprehension (and even apprehension) on the part of the general public about the engineering community and its works." NRC blamed this lack of understanding, in part, on the poor communications effort of present engineering societies.



MICHAEL WITTE

Frey, who had been an executive director of both AAES and one of its predecessors—the Engineers Joint Council—says inefficiency is also to blame. "There is so much duplication of effort," he says. Most societies have their own magazine, their own Washington representative, even their own group insurance policies. A unified organization, he maintains, would streamline operations.

Advocates of engineering unity say the present splintering hinders the solution of important national problems. Understanding acid rain, for example, involves knowledge of chemical, civil, environmental, and geological engineering, as well as air-pollution control; all five

disciplines have their own society, but there is no organization to facilitate the sharing of information between them.

Engineering education might also benefit from a more cohesive engineering community. "There is too much redundancy in engineering courses," says GM's Frosch. "Schools set up their departments along the traditional lines, but more important today are cross-disciplinary studies." One reason the old approach persists is that the Accreditation Board for Engineering and Technology—the organization that certifies engineering curricula—draws many of its officials from the existing engineering societies and thus mirrors their interests.

AAES associate director George Sibert says the organization has passed through its rough period, noting that after the first wave of resignations, membership has remained stable since 1983. He imputes the shaky beginning to shortsightedness on the part of many societies. "They ask, 'What is AAES going to do for *us?*' " In fact, he says, AAES will probably do very little for any one society; the organization should be seen as a "vehicle through which different kinds of engineers can speak as one." With AAES now doing business two blocks from the Capitol, Sibert adds, its voice has a far better chance of being heard by the nation's lawmakers. But given its reduced scale and membership, the organization may produce little more than a whisper. □ ***—Nicholas Basta***

New liquid crystals can be molded into durable parts

The chemical industry has recently achieved the long-sought goal of producing an injection-moldable liquid crystal polymer. This class of materials could conceivably replace metals, ceramics, composites, and engineering plastics in high-performance applications because their dense and highly ordered molecular structure makes them both lightweight and strong. The demand for such polymers could evolve into a market totaling 10–20 million pounds per year and valued at $100 million, according to the market research firm Business Communications (Stamford, Conn.).

The new polymer, Xydar—which can be injection-molded into a great variety of sizes and shapes at high production rates on modified conventional equipment—is produced by Dartco Manufacturing (Augusta, Ga.). The company claims that Xydar retains its strength even at extreme temperatures (−60° to 355° C), exhibits a tensile strength of about 17,500 pounds per square inch (psi), and has a stiffness of 1,600,000 psi at room temperature. "In addition to Xydar's outstanding strength," says Anthony Cetrone, Dartco's president, "it is highly resistant to virtually all chemicals, radiation, weathering, and burning." As a result, Dartco is evaluating it for ordnance components, aerospace parts, and three-dimensional printed circuit boards. Celanese (New York) is planning to produce liquid crystal polymers for making injection-molded parts to encapsulate integrated circuits, and for strengthening fiber optic cables. In 1986 the company will start up a 200,000-lb/yr pilot plant in Summit, N.J.

The development of an injection-moldable liquid crystal polymer has taken a long time mainly for three reasons. Most important was the reluctance of manufacturers to commit the resources necessary to produce one or more expensive monomers—essential for making the polymer but perhaps useful for nothing else—in large amounts (about 10 million pounds per year is considered the minimum for a commercial facility). In fact, Dartco intends to produce only one of the monomers needed for Xydar: biphenol. The other necessary monomers—terephthalic acid and *p*-hydroxybenzoic acid—the company will continue to purchase.

The second drawback was price. Dartco is offering Xydar in three grades for $28–$30 per pound—far more than engineering plastics usually cost. But the company maintains that when the monomer plant goes on-stream early next year and sales volume develops, the price of Xydar will come down.

The final deterrent to development of these polymers was the difficulty of creating a product that could be melted and remelted several times and still retain a predictable rheological profile (viscosity from melt to crystal). Many early products would vary in viscosity upon repeated melts; this deficiency resulted in inconsistent molding characteristics and virtually eliminated the possibility of recycling.

"The trick was to find a material that has a sufficiently high melting temperature to provide mechanical usefulness but that is also chemically stable enough to retain its integrity when you go above that temperature and remelt it," says Guy Berry, professor of polymer science and chemistry at Carnegie-Mellon University.

An unpredictable rheological profile occurs because the temperature required to melt the polymer is so high that a chemical reaction takes place among the molecules themselves or between the molecules and oxygen, changing the composition of the material. Xydar, which has a melting temperature of 423° C, can be remelted at least five times without changing its rheological profile, according to Dartco. □ ***—Richard Zanetti***

A brighter way to guide laser light

The carbon dioxide laser has become a standard tool in the fast-growing field of laser surgery largely because of its efficiency: A small package can deliver enough light power to cut through tissue. But a major factor inhibiting greater use of the CO_2 laser has been the lack of a satisfactory way to carry the beam to the patient. Prospects for CO_2 laser surgery are brightening, however. Last spring, two companies demonstrated flexible waveguides for transmitting CO_2 laser light that have industrial as well as medical applications.

CO_2 lasers can remove thin layers of tissue without damaging surrounding areas because their infrared wavelength of about 10 microns is absorbed very strongly by the water that makes up about 90% of the body. But that wavelength is also absorbed by the silicate glasses that make up conventional optical fibers, such as those used

for lightwave communications. Therefore the infrared beam has to be carried from the laser to the patient via a bulky series of jointed pipes with focusing optics at the elbows. These "articulated arms," resembling dentists' drills, are expensive and awkward to use. Moreover, they cannot deliver light inside the body.

Several companies in the U.S. and overseas have been working on waveguides for carbon dioxide lasers, and in May both Laakmann Electro-Optics (San Juan Capistrano, Cal.) and International Endoscope Manufacturers (Fort Washington, Pa.) demonstrated prototypes and announced plans for commercial versions. Other companies developing waveguides for CO_2 lasers include Fuller Research (Vernon Hills, Ill.), a subsidiary of Abbott Laboratories; CVD (Woburn, Mass.); Mochida Pharmaceuticals (Tokyo); and Laser Industries, an Israeli maker of surgical lasers.

These firms say their flexible devices will cost roughly a tenth as much as an articulated arm. However, considerable development is still needed. "We don't think anything is ready to be a product yet," says Joseph Masters, president of Ionomet (Lincoln, Mass.), which is studying fibers for CO_2 laser surgery under a grant from the National Institutes of Health.

Because no company has yet received approval from the Food and Drug Administration for using the waveguides in surgery, a nearer-term application will be in industry. Both of the recently demonstrated devices can handle the moderate power needed for marking surfaces and soldering electrical connections.

Although most technical details are proprietary, it is clear that Laakmann and International Endoscope follow fundamentally different approaches. Laakmann uses a hollow metal pipe with a 1×1–millimeter internal cross section; the laser's infrared radiation is constrained to the path of the pipe because the beam's electromagnetic field falls to zero at the conductor. (Similar structures have long been used to guide microwaves.) In contrast, International Endoscope makes fibers out of optical materials that, unlike ordinary glass, are transparent at 10 microns. The company says the fibers are polycrystalline metal halides but declines to specify the composition; possibilities include sodium chloride and other materials combining transparency at 10 microns with nontoxicity—an important concern for medical applications.

Both waveguides can deliver 10–20 watts of laser power, which is adequate for laser surgery. But they differ considerably in flexibility. International Endoscope's steel-jacketed fiber can attain a 4-inch bend radius without breaking; the Laakmann waveguide risks permanent kinking and decreased transparency if bent any tighter than an 18-inch radius.

Other fiber compositions being studied have their own limits. CVD has ground and polished fibers from rods of zinc selenide, which is commonly used for CO_2 laser windows and lenses. CVD hopes that a zinc selenide fiber produced by the more conventional technique of extrusion will be more flexible than the rather stiff specimens fabricated so far. Silver halide fibers being studied by Ionomet, Mochida, and Laser Industries are well understood and nontoxic, but fragile. Another drawback: Like the photographic film made from the same class of compounds, they tend to darken upon exposure to light.

Laakmann, International Endoscope, and CVD talk of selling waveguides for hundreds of dollars a meter in a couple of years. While that is far more expensive than mass-produced communications fiber, it is cheap compared with the contraptions the waveguides would replace; articulated arms run close to $4000. □ *—Jeff Hecht*

Low-cost satellite to aid developing countries

An inexpensive communications satellite is being developed to transmit technical information to widely scattered groups and individuals throughout the third world. Called PACSAT, the satellite will be based in low earth orbit and will communicate digitally with unsophisticated ground stations. PACSAT is a joint effort of two nonprofit organizations: Volunteers in Technical Assistance (VITA—Arlington, Va.) and the Radio Amateur Satellite Corp. (AMSAT—Silver Spring, Md.), a group of ham radio operators who have been involved for many years in amateur space communications.

If all goes as planned, PACSAT will be carried aboard the Space Shuttle in early 1987 inside a Getaway Special cannister. It will be deployed at an altitude of 429 miles, in a polar orbit that puts it within range of any spot on earth at least twice every 24 hours. (In contrast, conventional communications satellites orbit at a geosynchronous altitude of 22,300 miles, which allows them to provide real-time communications but limits coverage to only one hemisphere.) PACSAT will employ a "mailbox" system in which ground-station messages are transmitted digitally to the satellite as it passes overhead, stored in random-access memory, and then retransmitted to another ground station later in the orbit. The ground stations—which will cost less than $3000 each—will consist of a personal computer and printer, a receiver/transmitter, and an antenna.

The primary purpose of PACSAT, according to Anne Heyniger, public information officer at VITA, will be to transmit agricultural and technical information to developing countries. "We see agricultural extension agents using PACSAT in offices, relief workers using portable PACSAT ground stations powered by solar panels or batteries, and universities using PACSAT to communicate with databases all over the world," she says. As currently envisioned, the satellite will have enough memory for about 900 pages of text, enabling it to store and transmit complete documents as well as shorter messages.

The feasibility of mailbox communications from low earth orbit was tested in January using a package called the Digital Communications Experiment, which was built by a team of AMSAT and VITA volunteers. Carried aboard the UoSAT-2 communications satellite, the experimental package transmitted messages from Hawaii to the University of Surrey in England in about 40 minutes.

VITA is presently raising money for the PACSAT project, which has thus far relied on volunteer work. The project's proposed $800,000 budget should cover construction of the satellite, a $10,000 Getaway Special reservation, and the creation of several ground stations. AMSAT and VITA will devote the first year of PACSAT's operation to proving the technology and obtaining FCC permission to use the amateur radio frequency for this purpose. According to Heyniger, VITA has already received letters expressing interest in PACSAT from individuals and organizations in 24 developing countries. □

—Jonathan B. Tucker

Contact

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—Jonathan B. Tucker

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TECHSTARTS

Seattle Silicon:
AUTOMATING CIRCUIT DESIGN

The trend toward customizing integrated circuits for specific applications depends on a series of advances in engineering automation. One is a software tool known as a silicon compiler, which helps engineers design circuitry and lets them dispense with the laborious task of laying out complex circuit paths by hand. Seattle Silicon introduced its compiler, Concorde, on engineering workstations from Valid Logic, but the package will soon be available on workstations from Mentor and Tektronix as well. Unlike similar tools from competitors such as start-ups Silicon Compilers Inc. and MetaLogic, Concorde can automatically lay out analog as well as digital circuits.

Financing: $6.2 million in venture capital from investors including Norwest Growth Fund, Hambrecht and Quist, Rainier Venture Partners, and Canadian Enterprises Development.

Management: President Gordon Kuenster was VP of Squibb's Medical Systems Group and was previously president of Advanced Technology Laboratories. Peter van Oppen, head of the workstation division—one of the company's two operating units—was president of electronics company Systems Northwest and earlier was international VP of Squibb's Medical Systems Group. George Cone, head of contract services, the second operating unit, cofounded Applied Micro Circuits, a maker of bipolar arrays, and previously was president of Array Devices.

Location: 12356 Northup Way, Bellevue, WA 98005, (206) 883–2176.

Founded: April 1983.

Seattle Silicon's Concorde automates much of the integrated-circuit layout process.

Arity:
BRINGING A.I. TO PERSONAL COMPUTERS

For a computer to simulate even the simplest human reasoning process is a highly complex affair—which is why most artificial intelligence software runs on very powerful machines. But researchers at Arity have managed to condense some AI programs enough to run even on personal computers. Arity is developing its products for the IBM PC and will base them on its own version of the AI programming language Prolog. The company, which already has two language tools—a compiler and an interpreter—on the market, is aiming its Prolog tools at software developers. It also plans to bring out AI-based business productivity software for the general market.

Financing: $1 million in venture capital from software company Lotus Development and UST Capital, a division of United States Trust of Boston.

Management: Cofounders Peter Gabel (president) and Peter Weiss (VP of R&D) left Lotus to form the company. Gabel was development manager of 1-2-3 at Lotus and previously was a software manager for Digital Equipment. Weiss was a member of Lotus's advanced development group and previously wrote software for Digital. Director of finance and administration Richard Kohn managed venture investments for UST Capital.

Location: 358 Baker Ave., Concord, MA 01742, (617) 371–1243

Founded: March 1984.

Endo-Lase:
CUTTING SURGICAL RISK WITH LASERS

Lasers are rapidly replacing the less precise scalpel in medical procedures that range from repairing detached retinas—where laser surgery is now the norm—to neurosurgery. With YAG (yttrium-aluminum-garnet) lasers, it's even possible to perform general surgery without having to make incisions, by passing an endoscope (a tube containing optical fibers) into body cavities and using it to guide the beam. Endo-Lase is the U.S. distributor for the mediLas YAG laser made by Angewandte Technologie, a subsidiary of West German aerospace company MBB. The mediLas is one of the first YAG lasers to receive FDA approval for a variety of surgical procedures, giving Endo-Lase an early start in an increasingly crowded market that includes giants like American Hospital Supply and Squibb.

Financing: $4.3 million from a January 1984 initial public offering of 920,000 units (each consisting of three shares and a stock warrant) at $6 per unit, underwritten by D. H. Blair (New York). $3.5 million from a later exercise of stock warrants.

Management: Founder, chairman, and CEO Michael C. Clinger was chairman and majority owner of Advanced Surgical Technologies, a distributor of CO_2 medical lasers, before the company was acquired by Laser Industries. He was previously CEO of Litechnica S.A., the Swiss branch of a British medical equipment distributor. President and COO Walter G. Solomon was managing director of Litechnica Ltd. (U.K.) and was previously director of I. Solomon & Co., a textile manufacturer.

Location: 10 Columbus Circle, New York, NY 10019, (212) 757–7800.

Founded: January 1982.

INDUSTRIAL LASERS GET HOTTER

Automated manufacturing is driving rapid growth

Industrial laser systems constituted a $400 million worldwide market in 1984, mostly in material processing and inventory control, and this market will likely reach over $1 billion by 1990. The current 33% annual growth rate for such lasers is being driven by their potential for increasing manufacturing productivity, through both the better use of automated machining technologies and the improved availability of parts.

In material processing, carbon dioxide and solid-state laser systems costing up to $400,000 are used largely for faster and more accurate metal cutting, welding, drilling, and heat treating, and to a lesser extent for cutting and drilling plastics, ceramics, and other nonmetals. Lasers can be used as human-guided machine tools, but for more precise metalworking they must be linked to computer-controlled systems. As one component of the automated factory, a robot-driven laser can be programmed to adjust the size of a cut, for example, with precision and minimum downtime. Automotive, aerospace, and electronics firms are among the leading users of such lasers.

The other major industrial segment draws on helium–neon and semiconductor lasers costing under $100 (excluding the associated computer equipment) for counting, measuring, aligning, and inspecting parts or products. Interest in sophisticated technology for reading bar codes and for other numerical inventory-control systems has been stimulated by the increased use of just-in-time methods for distributing parts. Among other things, these methods require accurate, constantly monitored counting of individual items. For this task, bar code readers that use lasers are less error-prone than those that use noncoherent light, especially when scanning bar codes at an angle.

The industrial laser field has attracted over 300 companies, most of which make laser products for other applications as well. Although it can be risky to invest in such a crowded field, not all of whose members will survive, several public companies are well positioned to take advantage of growth in this market. They include Coherent (Palo Alto, Cal.), Lumonics (Kanata, Ont.), and Symbol Technologies (Bohemia, N.Y.).

Coherent (OTC: COHR) is the leader in material-processing lasers, with 30% of the market. Half the firm's business is in lasers for cutting and welding, with remaining sales divided between medical and scientific systems. In June 1984, the company widened its base considerably by joining General Electric in the formation of Coherent General. Coherent retained a 60% interest in the new entity, which will develop and market Coherent's material-processing lasers. In addition to financial backing, this venture brings in General Electric's experience as a producer and user of factory automation equipment with which Coherent General's products can be integrated.

Last year Coherent had revenues of $111 million—an increase of 22% over its $91 million sales in 1983. Profits were $6.2 million, and earnings per share were $1.65 in 1984, up from $1 million and 58¢ per share in 1983.

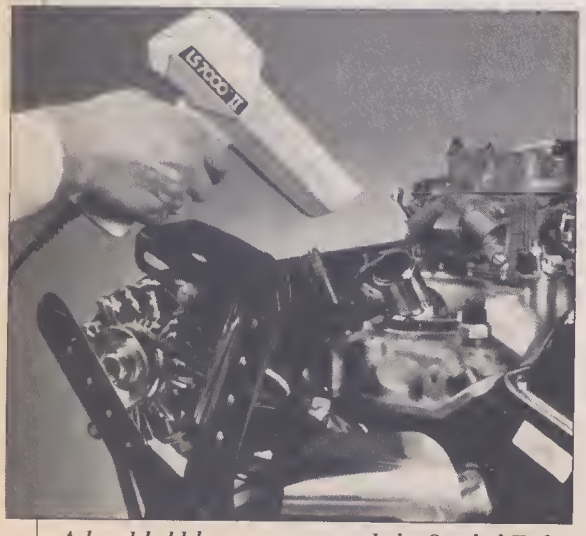
Lumonics (TSE: LUMT) is the third largest manufacturer of commercial lasers in the world, offering products for material processing, ophthalmology, scientific laboratory work, and other applications. The company markets a carbon dioxide laser marking system called LaserMark. This device delivers an improvement over traditional ink-based markers, which may not accurately imprint information on rough or irregular surfaces. Over 1300 LaserMark systems have been sold worldwide to apply "best used before" dates on supermarket items and to mark electronic components with ID numbers and final-tested values.

Lumonics achieved 1984 revenues of $38 million, yielding $5.7 million in net income and earnings of 70¢ per share, versus $22 million in revenues, $3.2 million in net income, and 42¢ per share in 1983.

Symbol Technologies (OTC: SMBL) has lost money every year since its inception in 1979, in part because of capitalization costs and problems in expanding beyond low-volume production. Unlike Coherent and Lumonics, Symbol makes only one product—hand-held and stand-mounted laser bar code readers—and thus offers riskier investment prospects. However, the company's newest Laserscan product line has received significant orders from retail chains such as Wal-Mart and Rite Aid, as well as from the U.S. Post Office and the Department of Defense. As a result, the firm should now have a base for tapping industrial applications in inventory control.

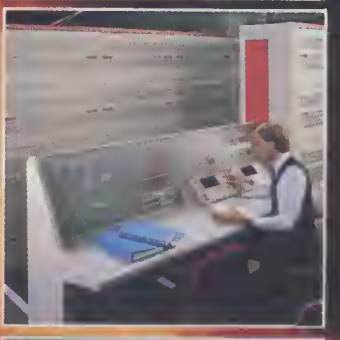
In 1984, Symbol logged sales of $8.6 million and losses of 61¢ per share, up from $3.4 million and 50¢ the year before. □

by James S. Williams



A hand-held laser scanner made by Symbol Technologies reads bar codes.

James S. Williams is founder of LaserTrends, a database service based in Longmeadow, Mass.



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